Water Works and Sewerage

Vol. LXXVI SEPTEMBER, 1929 No. 9

New Service Building of the Portland Water District

New England Water Works Association Holds Annual Meeting at Portland

Program of 48th Annual Convention of Association

THE 48th annual convention of the New England Water Works Association will be held at Hotel Eastland, Portland, Me., September 17, 18, 19 and 20.

The convention office of the secretary will be located in the lobby on the first floor, Hotel Eastland, and will be opened for registration at 3 p. m., Monday, September 16. The registration office will not be open evenings after 6 p. m.

Technical Meetings and Exhibits.—The exhibits will be located in the Sunrise room of the hotel. Technical sessions will be held in the ballroom and other rooms as posted. Victor E. Arnold, of the Pittsburgh Equitable Meter Co., New York, is chairman of the committee on exhibits.

Transportation.—Portland is reached by three railroads, the Maine Central, the Boston & Maine and the Grand Trunk. No special arrangements have been made with any of the railroads for transportation, as many of the members of the association wish to go to Portland by automobile.

Electric car lines serve the city and its suburbs, and give first-class service to the beaches and near-by resorts. Portland's airport, in the town of Scarboro, about six miles from the center of Portland, is one of the largest and best equipped in the east.

Program.—The program, as arranged by the program committee, of which Robert Spurr Weston is chairman, follows:

TUESDAY, SEPTEMBER 17

Morning Session, 10:00 a. m.

Address of Welcome by
His Excellency William Tudor Gardiner, Governor of Maine.
Lester F. Wallace, Chairman Board of City Councilmen, City of Portland.
William L. Blake, President Board of Trustees, Portland Water District.

Secretary's Report
Treasurer's Report
Editor's Report
Award of Dexter Brackett Medal
Committee:
Gordon M. Fair, Chairman
Frank A. McInnes
G. Earl Lourie

Closing of Polls
Appointment of Tellers

REPORTS OF COMMITTEES ON

Tests of the Bureau of Standards, Harry W. Clark, Director and Chief Chemist, Water and Sewage Laboratories, Mass. Department of Public Health, Chairman.

The Collection and Correlation of Information Concerning the Corrosion of Iron and Steel Pipes and Standpipes, Caleb M. Saville, Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn., Chairman.

Standardization of Pipe Flanges and Fittings, Wm. R. Conard, Conard & Buzby, Burlington, N. J., Chairman.

Specifications for Cast-Iron Pipe and Special Castings, Chas. W. Mowry, Assistant Manager, Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., Chairman.

Of the Sponsors for the Section Committee on Standardization of Cast-Iron and Special Castings, Wm. R. Conard, Conard and Buzby, Burlington, N. J., Chairman.

Standard Specifications, C. W. Mowry, Assistant Manager, Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., Chairman.

Standardizing the Steps of the Meter Schedule, Arthur E. Blackmer, Superintendent of Water Works, Plymouth Mass., Chairman.

Wrought-Iron and Wrought-Steel Pipe and Tubing, Chas. W. Mowry, Assistant Manager, Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., Chairman.

What Arrangements Can Be Made Toward Carrying Out Some of the Experiments Which Dr. Barnes Would Like to Make in Connection with Using Thermit Heat Units on Frozen Hydrants, Etc., P. R. Sanders, Superintendent of Water Works, Concord, N. H., Chairman.

Yields of Catchment Areas, X. H. Goodnough, Director and Chief Engineer, Massachusetts Department of Public Health, Chairman.

Convention Committee, 1929, James W. Graham, Treasurer and General Manager, Portland Water District, Portland, Maine, Chairman.

Afternoon Session, 3:30 p. m.

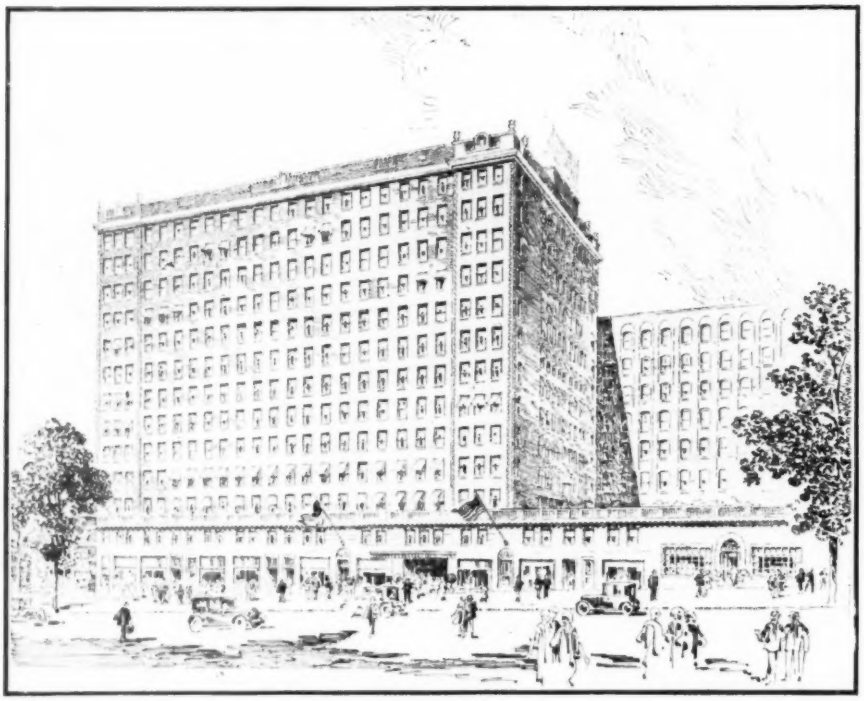
A Description of the System of the Portland Water District by James W. Graham, Treasurer and General Manager, Portland Water District.

History of the Organization of the Portland Water District by David E. Moulton, Clerk and Attorney of Portland Water District.

Beauty in Water Works Structures by John Calvin Stevens, Architect.

Evening, 7:30 p. m.

Color Reduction in Storage Reservoirs by Caleb Mills Saville, Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn.



Hotel Eastland, Portland, Me., Headquarters of New England Water Works Association Convention

A Study of Color Removal by H. W. Clark, Director and Chief Chemist, Water and Sewage Laboratories, Massachusetts Department of Public Health.

WEDNESDAY, SEPTEMBER 18

Morning Session, 9:00 a. m.

A Year's Experience with Automatic Chlorination at Concord, N. H., by Percy Sanders, Superintendent of Water Works, Concord, N. H.

Typhoid Fever in Eastern United States by Chester F. Drake, Superintendent of Filtration, Pittsburgh, Pa.

Evening, 7:30 p. m.

Superintendents' Meeting

Report of Legislative Committee.—S. S. Anthony and George A. King.

Report of Committee on Painting Standpipes.—A. O. Doane, Chairman.

Followed by a General Discussion.

Test of Large Meters in the Field by R. F. Ferguson, Assistant Superintendent, Hersey Mfg. Co., Boston, Mass.

Experience with Diesel Engines in Water Works Plants by A. D. Couch, Mechanical Engineer, Community Water Service Co., New York City.

THURSDAY, SEPTEMBER 19

Morning Session, 9:00 a. m.

Method of Testing Cast-Iron Pipe by Wm. R. Conard, Conard & Buzby, Burlington, N. J.

Paper by E. E. Lochridge, Chief Engineer, Springfield Water Works, Springfield, Mass.

Afternoon Session, 2:30 p. m.

The Reconstruction of the Pumping Station of the Western New York Water Company at Buffalo in Connection with the Construction of a 20,000,000-Gallon Filter Plant, by H. W. Huy, General Manager, Western New York Water Co.

Making of Water Flow and Pressure Studies by the Water Works Engineer by Herbert E. Smith, of the Simplex Valve and Meter Co., Philadelphia, Pa.

FRIDAY, SEPTEMBER 20

Morning Session, 9:00 a. m.

Watching the Weather in Safeguarding Public Water Supplies by Arthur E. Gorman, Sanitary Engineer, Wallace & Tiernan Co., Arlington, N. J.

Changes in Power for Pumping at Newport, R. I., by Harold Watson, Superintendent of Water Works, Newport, R. I.

Report of Tellers—Election of Officers. President's Address.

Entertainment.—Burt B. Hodgman, chairman of the entertainment committee, has announced the following program:

TUESDAY, SEPTEMBER 17

1:00 p. m.—Maine clam chowder luncheon at new shops of Portland Water District followed by inspection of shops and standpipe painting inspection. Ladies are invited. (Courtesy of Portland Water District.)

8:00 p. m.—Informal reception for ladies at Hotel Eastland.

8:15 p. m.—Theatre party for ladies. (Courtesy of Geo. F. West & Son.)

WEDNESDAY, SEPTEMBER 18

11:30 a. m.—Clam bake and sail, Casco Bay. (Courtesy of Water Works Manufacturers' Association, Inc.)

8:00 p. m.—Ladies' Reception and bridge at Hotel Eastland. (Courtesy of Water Works Manufacturers' Association, Inc.)

THURSDAY, SEPTEMBER 19

10:00 a. m.—Sight-seeing trip for the ladies. Buses leave Hotel Eastland 10:30 a. m. (Courtesy Portland Chamber of Commerce.) Followed by coffee at Portland Chamber of Commerce.

7:30 p. m.—Dinner-dance and entertainment at Hotel Eastland. (Courtesy of Water Works Manufacturers' Association, Inc.)

Golf Tournament.—(Time to be announced.)

FRIDAY, SEPTEMBER 20

10:00 a. m.—Shopping tour through Portland business district. (Courtesy of Portland Chamber of Commerce.)

Operating Experiences With New Water Softening Plant at Marion, Ohio

Double Carbonation Produces Effluent of Low Alkalinity

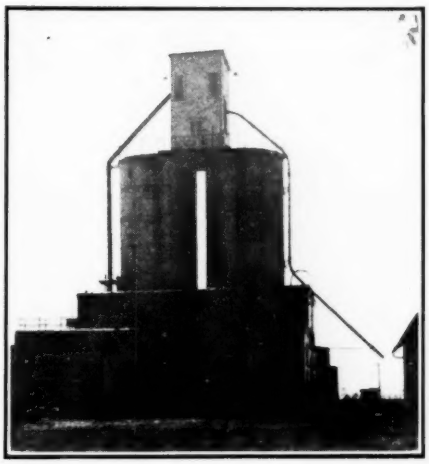
By MARTIN E. FLENTJE and CHARLES WHYSALL

Superintendent of Purification, Community Water Service Co.; Chemist in Charge, Marion Water Co.

THE water softening plant of the Marion, Ohio, Water Co., a subsidiary of Community Water Service Co. of New York City, is unusual from several standpoints. Probably first of all is the extreme hardness of the water being treated; secondly, the use of all steel construction above ground; and finally in the application of double carbonation to produce an effluent of low alkalinity.

The Supply.—Water is at present obtained from 14 wells in limestone, varying in depth from 140 to 225 ft. Motor driven pumps deliver the water to collecting troughs leading to a concrete basin. During passage through these troughs and while spraying over small aerators, the raw water loses some CO_2 gas, and the dissolved iron is oxidized. Oxidization and precipitation of the iron results in an apparent turbidity of 150 p.p.m. in the collecting basin. Typical partial analyses of well waters are given in Table I.

The Softening Plant.—The water is pumped to the two 30 ft. in diameter mixing tanks, receiving on its way the milk of lime prepared in the headhouse. Browning-Montgomery chemical dry feeders are used. A 100 g.p.m. capacity



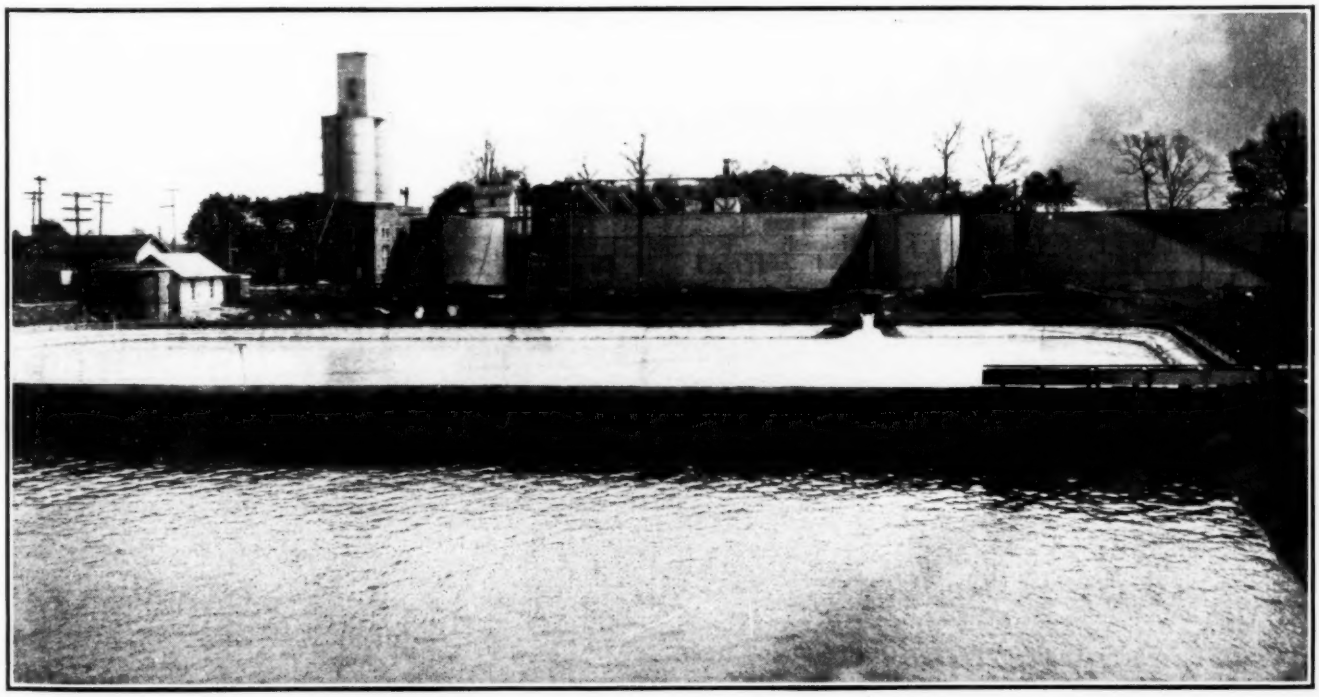
Chemical House and Chemical Storage Tanks; Airneyar Filter House

ejector adds the lime water to the water to be treated, while the former soda ash injector has been replaced by a small centrifugal pump.

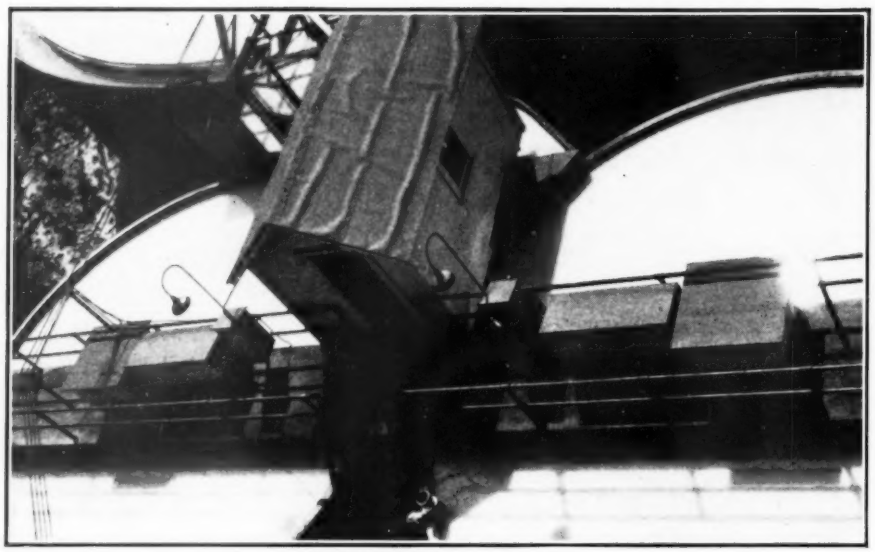
Soda ash is applied at the top of the second mixing chamber. Marble Cliff (Ohio) Pebble Lime and Solvay Soda Ash are used. The mixing basins are 24 ft. in height, as are all other basins. A single paddle is located near the bottom, and is driven by a variable speed motor. Water enters tangentially at the bottom, spirals upward, overflows into the bottom of the second basin and repeats the process. The retention period in the mixing basins is 4-5 hours at the present rate of flow, with a minimum retention of 1 hour at plant capacity.

From mixing chambers, the water flows to the 120 ft. diameter Dorr Clarifier, flowing into the 30 ft. stilling chamber in the center 12 ft. downward, and then outward, finally overflowing into the launders at the periphery of the tanks. The sludge is removed from this clarifier by means of Dorr sludge pumps and contains between 65-75 per cent moisture.

The second settling tank is not equipped with clarifier mechanism, although the stilling well, etc., are arranged for its installation if found desirable. In this stilling well carbonation of the free lime present to normal carbonates is carried on, and some alum added. A retention period at plant capacity of 19 hours has been provided for in each basin; at present rate of



View of Water Softening Plant at Marion, O., Showing, Left to Right, Mixing Tanks, Dorr Clarifier, Final CO_2 Chamber and Settling Tanks



Mixing Tank and Sludge Pump House

flow 48 hours is the period. An effluent having a turbidity of 2 p.p.m. or less is produced in the Dorr Clarifier, with a final plant effluent turbidity of less than 1 p.p.m.

Final carbonation is carried out in a carbonating basin, 26 ft. in diameter with a retention period at present of 1¾ hours.

Chemicals are unloaded by vacuum, an Airveyor system being used.

Operation.—A number of laboratory tests indicated that with a lime dosage of 25 grains per gallon, or a theoretical excess of 6 grains; a minimum of soda ash required with a maximum hardness removed would results. Such a lime dosage insured complete precipitation of all the magnesium present, and eliminated some of the troublesome complex reaction products, commonly resulting in high alkalinities. This lime dose resulted in a causticity or free lime content of 30 p.p.m.—and this figure has been used as a guide in the treatment control. The soda ash dose is varied with the raw water hardness and to give any desired plant effluent. Typical analyses of various steps in the softening process are given in Table II.

Average operating results for various months are given in Table III.

Some operating difficulty has been experienced in preventing the clogging of the chemical feed lines. Sufficient diluting water has, however, solved this problem so well that the present lime line has not been cleaned for 8 months, and the cleaning time for the soda ash line has been extended from weekly periods to periods of 30 days.

Discussion of the proper place to carbonate to the normal carbonate stage led to an experimental installation of a carbonating grid at the influent to the Dorr Clarifier. This location was considered as practically identical with carbonation directly in the mixing basin effluent. The results of this experiment were quite unsatisfactory, as low alkalinities could not be obtained and very poor settling resulted. Higher causticities were apparently carried in the mixing chamber during the time of making this test and insufficient CO_2 gas added. Plotting the daily results, however, indicates that the poor results must have been due to some obstruction to the reaction between the CO_2 and the free lime—as at various times very high causticities have not resulted in high effluent alkalinities when the first carbonation was carried on in partially clarified water. Carbonating at this point also resulted in the formation of very small floc particles which would not settle readily. The turbidity of the plant effluent was increased from 1 p.p.m. or less to 10 or 15 p.p.m.

An inspection of Table III shows that a decrease in the pounds of soda ash per m.g. had occurred. This is probably due to increased time of retention in the mixing basins. A change in the rate of flow through the basins is apparently directly reflected in the soda ash required.

This decrease in soda ash required represents a saving of approximately $4.00 per million gallons, or an additional removal of approximately 30 p.p.m. hardness (non-carbonate) with the same chemical dose formely used.

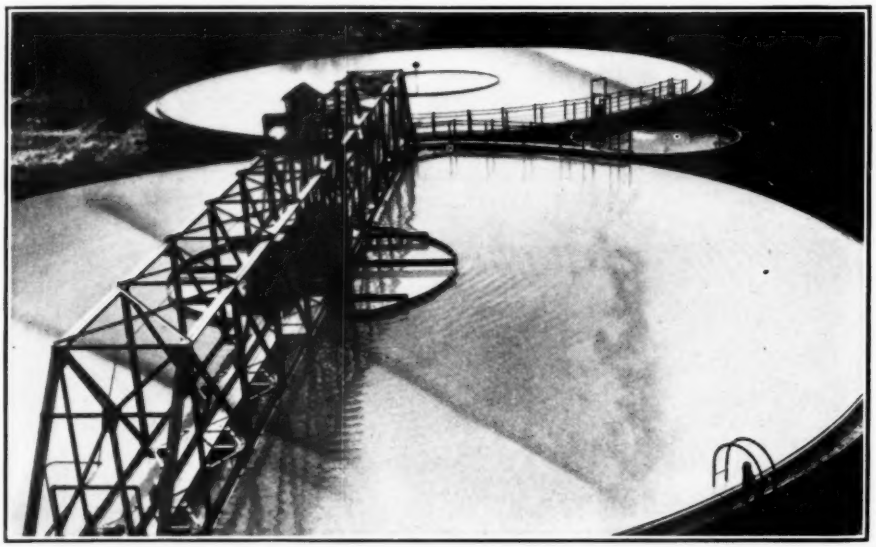
Double carbonation has resulted in alkalinities averaging 30-35 p.p.m., whereas in laboratory tests without double carbonation, alaklinities below 65 p.p.m. could not be produced. Double carbonation has then resulted in a removal of 30 p.p.m. hardness at a cost of practically nothing, a constant

Table I—Typical Well Water Analyses Marion, Ohio

Well No.	No. 2	No. 4	No. 15	No. 17	No. 25	No. 20
Alkalinity (as $CaCo_3$)	312	318	306	275	306	240
Non-Carbonate Hardness	736	529	392	507	294	452
Total Hardness	1048	847	698	782	600	692
Magnesium	56	47	45	49	38	46
Free CO_2	72	67	57	59	35	45

Table II—Typical Analyses at Various Steps in Softening Process—Marion, Ohio

	Raw	Mixed	Clarified	Settled after 1st Carbonation	Carbonated
Total Alkalinity p.p.m.	303	61	69	35	33
Phenol Alkalinity p.p.m.	0	50	59	19	6
Causticity p.p.m.	0	39	49	3	0
Non-Carbonate Hardness p.p.m.	438	168	109	111	106
Total Hardness p p.m.	741	229	178	146	139



Clarifier and Settling Tanks, View Taken from Top of Chemical Storage Tanks

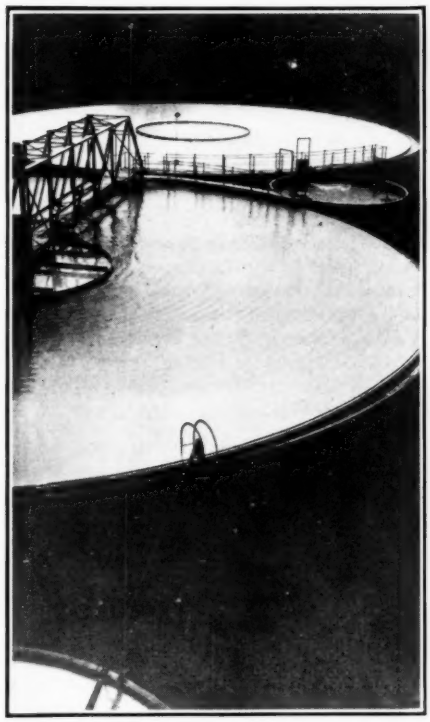
amount of coke being used, regardless of whether single or double carbonation is carried on. If, however, it is assumed that ½ of the total coke used is necessary to produce this result, costs would be as in Table IV.

Sludge disposal is rapidly becoming a serious problem and considerable study is being given this problem. No practical solution, however, has as yet been found.

The temperature changes taking place through the plant may be of interest. The well water has a constant year around temperature of 54 deg. F. During the winter the water in the basins gets as low as 37 deg.

The Marion Water Co. softening plant was designed by C. P. Hoover of Columbus and constructed under the direction of Geo. Whysall, manager of the Marion Water Co., under immediate supervision of Chas. Whysall, now chemist in charge.

Acknowledgment.—The above is an abstract of a paper presented at the 49th annual convention of the American Water Works Association.



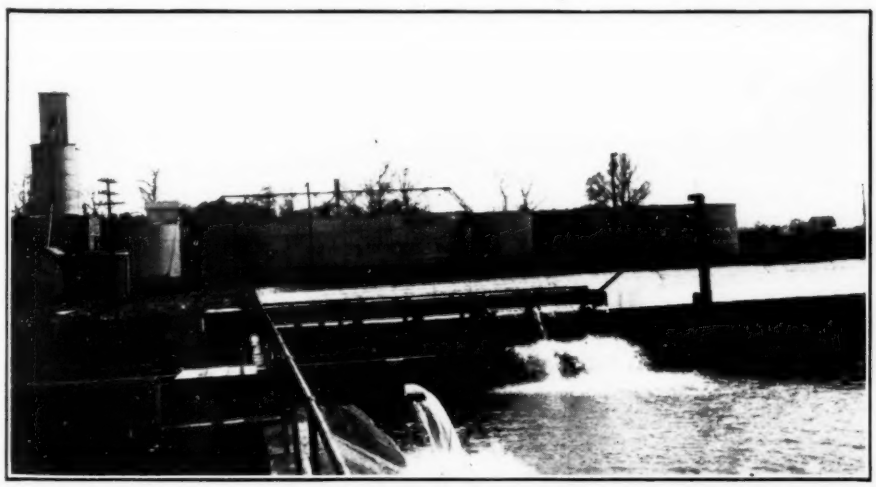
Clarifier, Settling and Carbonation Tanks

Table III—Average Operating Results—Marion, Ohio

	Gallons treated m.g.	Lime lbs. per m.g.	Soda Ash lbs. per m.g.	Alum lbs. per m.g.	Coke lbs. per m.g.	Lime data lbs. per m.g. per p.p.m. alkalinity reduced	lbs. per m.g. per p.p.m total alkalinity	Soda Ash lbs. per m.g. per p.p.m. non-carbonate hardness removed
Aug.	42,234	3,775	2.875	39	293	13.8	12.3	11.8
Sept.	30,663	3,040	3,040	34	391	15.4	13.9	13.8
Oct.	28,000	2,970	2,970	37	443	16.0	14.3	11.9
Nov.	30,247	3,061	3,061	56	204	15.7	14.1	10.1
Dec.	30,601	3,057	3,057	49	101	14.6	12.7	10.5
Jan.	31,142	3,080	3,080	47	99	14.9	13.2	10.6
Feb.	32,057	3,090	3,090	45	87	14.3	12.6	10.4
Mar.	32,785	3,115	3.115	55	100	14.2	12.5	9.9

Table IV—Cost of Removing Hardness by Double Carbonation

Month	Total coke lbs. per m.g.	Assumed cost per m.g. of carbonation	Cost per p.p.m. hardness removed	Total ave. cost for removing 1 p.p.m. hardness (with lime and soda ash)
Aug.	293	$0.51	0.014	
Sept.	391	0.68	0.019	
Oct.	443	0.77	0.021	
Nov.	204	0.70	0.021	
Dec.	101	0.35	0.010	
Jan.	99	0.34	0.010	
Feb.	87	0.31	0.009	
Mar.	100	0.35	0.010	
Ave.				$0.097



View Shows Corner of Raw Water Basin in Foreground; Also Two of the Aerating Troughs

Survey of Fire Hydrants in New Jersey

The recent survey of fire hydrants in North Hudson and Eastern Bergen counties covering 48 cities and towns supplied by the Hackensack Water Co. revealed a wide variation in the average spacing of these outlets of the water distribution system, according to a report made public by the president of the company, Nicholas S. Hill, Jr.

"In North Hudson County," says the report, "the extremes are West New York, 438 ft., compared with Secaucus, 781 ft., between hydrants.

"In Bergen County, the difference is more striking when one compares Edgewater, 352 ft., with Washington Township, 1,830 ft. It is, however, only fair to point out that Edgewater has large industries concentrated along a narrow belt of water front, whereas Washington Township is but recently opened to what promises to be a successful development.

"Taking all towns it is found that four have hydrants averaging less than 500 ft. apart, six have hydrants averaging from 501 to 600 ft. apart, six have hydrants averaging from 601 to 700 ft. apart, twelve have hydrants averaging from 701 to 800 ft. apart, five have hydrants averaging from 801 to 900 ft. apart, four have hydrants averaging from 901 to 1,000 ft. apart and ten have hydrants averaging over 1,000 ft. apart. The general average of all is 740 ft.

"The distances between hydrants over 1,000 ft. apart are, in the ten towns, 1,023, 1,070, 1,100, 1,150, 1,155 1,157, 1,204, 1,220, 1,392 and 1,830.

"If firemen must stretch two lines of hose, each at least 600 ft. long, to reach a burning dwelling midway between two hydrants 1,150 ft. apart, they are compelled to substitute the limited capacity of 2½-in. crooked hose for the far greater flow of an iron water main at least 6 in. in diameter which passes the dwelling and should properly have a hydrant connected to it at about that point."

Fire chiefs, the water company officials point out, are alive to the menace of such situations, and are on record as requesting municipal officials to order additional outlets attached to the existing water mains.

Symbols for Hydraulics.—The proposed American tentative standard symbols for hydraulics have been adopted by the sectional committee on scientific and engineering symbols and abbreviations and by the five sponsor bodies. The report is now being balloted by the American Standards Association. Copies of the proposed American Tentative Standard are available for review by those interested, and may be obtained on loan from the American Standards Association Information Service, 29 West 39th St., New York City.

Activated Sludge Practice in United States

General Features of Design and Treatment in Twelve Plants

EARLY in 1928 the Board of Estimate and Apportionment of New York City appointed a special committee consisting of C. W. Berry, controller, and Arthur S. Tuttle, chief engineer, to inspect methods of sewage disposal in use in other cities.

In all 16 plants were inspected as follows:

Chicago, Ill.—North Side.
Chicago, Ill.—Calumet.
Chicago, Ill.—West Side.
Chicago, Ill.—Des Plaines River.
Indianapolis, Ind.
Antigo, Wis.
Milwaukee, Wis.
Lodi, Cal.
Pomona, Cal.
Pasadena, Cal.
Long Beach, Cal.
Harbor City, Cal.
Los Angeles, Cal.—Hyperion (North Plant).
Grand Canyon, Ariz.
Houston, Tex.—South Side.
Houston, Tex.—North Side.

The object of the inspection was to secure information as to the applicability of the activated sludge process to a plant on Ward's Island; whether it might be a source of nuisance to the neighborhood; whether it was so far developed as to be dependable in operation; and whether it would prove an economical solution for the disposal of the tributary sewage.

Eleven plants employing the activated sludge process, and a twelfth where it is employed in part, were visited, while the other plants contained special features, such as fine screens and sludge digestion, that bear directly upon the New York City problem.

The salient features of the plants visited are reviewed by Kenneth Allen, sanitary engineer, office of the chief engineer of the Board of Estimate and Apportionment, in a report of the special committee. The notes following are taken from the report.

Coarse Screens.—Coarse screens are generally placed in front of pumps, fine screens, or other devices requiring protection from large floating material that might cause injury. The usual form is the inclined rack of parallel bars, spaced up to 5 in. apart and cleaned by hand, but in large installations some mechanical equipment is desirable.

At the North Side Works, Chicago, at Milwaukee, and at the South Side Plant at Houston cage screens are used in pairs, one being in service while the other is raised by power and cleaned by hand. These screens are adapted to large flows and deep sewers, when the limited amount of manual labor is justified.

At the West Side Works, Chicago, and the Hyperion Plant, Los Angeles, the Dorrco coarse screen is used. This is simple in design and mechanically operated, the curved rack being cleaned by a rake connecting the outer ends of radial bars rotating on a horizontal axis. This is a revival of a type of screen used in Germany and may well be adapted to many situations.

Fine Screens.—Fine screens of the Riensch-Wurl type are in use at the Des Plaines River Works, Chicago; of the Tark or Link-Belt type at Milwaukee; of the Dorrco type at Lodi, Pasadena, Long Beach and Los Angeles; and of the Hurd type at Indianapolis. Those at Chicago, Milwaukee, Lodi, Pasadena and Indianapolis furnish preliminary treatment for the activated sludge process, while at Long Beach and Los Angeles their function is to protect near-by bathing beaches. The Milwaukee, Indianapolis and Los Angeles installations are important as to size and are excellent examples of their kind. In general the trend seems to be in favor of slotted plates rather than wire mesh, and with 1/16 in. x 2 in. slots.

There are so many factors upon which screen performance depends that comparisons are difficult. Tests, unless made in parallel on the same sewage, are liable to be grossly misleading and it is a question whether there is a material difference in efficiency in the above standard types of screen. If a fine screen is considered preparatory to activation the choice of fineness will depend somewhat on whether the sludge is to be made into fertilizer, in which case it may be desirable to permit more solids to pass through, in order to increase the marketable product, but the cost of aeration will probably be greater. If the screen is for the protection of the waterfront the end to be sought is the removal of solids offensive to sight, and for this any one of the above screens operating with a slot 1/16 in. wide will serve the purpose. While, as stated, individual tests vary greatly, average removal of about 10 per cent of the suspended solids may generally be expected, but whether this is 5 per cent or 15 per cent the main object of screening has been accomplished unless further protection by chlorination is necessary, in which case a high removal of solids to reduce the cost of chlorine may be desirable.

The removal and moisture at these plants is shown in Table I.

In choosing a fine screen it would seem that too much stress has been laid in the past on efficiency as shown by short tests. Reliability of performance, durability, first cost and upkeep are believed to be matters of much more importance, and concerning these information is gradually accumulating with longer experience.

The disposal of screenings by burying in small quantities and in rural areas is often the simplest and best method. Where the volume is large, as at Los Angeles and Long Beach, or where the plant is in urban territory, as at Milwaukee, the problem is more difficult and a choice must be made of several possible procedures.**

At Milwaukee experiments in digesting the screenings and then mixing them with the sludge going to the filters are proposed. Whether this will affect the filterability of the sludge unfavorably or not remains to be seen. It will probably dilute to a small extent the nitrogen in the dried sludge but will also increase the volume of the sludge, as occurs when plain settled sludge from preliminary tanks is added to the output of activated sludge.

At Hyperion the Los Angeles screenings are buried in the sand but are exposed to a certain extent by the gulls that are attracted to the spot and some more satisfactory method of disposal is being sought. Experiments reported by D. C. Warfel have indicated that by distillation there may be recovered from one ton of screenings 85 per cent moisture, about 800 cu. ft. of gas containing 400 b. t. u., 100 lbs. fuel oil and 150 lbs. of fertilizer base containing 1½ per cent nitrogen, 3.2 per cent phosphoric acid and 1.0 per cent potash, valued at 1.50 per ton of wet screenings. These experiments are to be extended and the foregoing results must be considered provisional.

Long Beach appears to have solved the problem of disposing of its screen-

*Weighing 135 lb. and containing 20 lb. dry solids in 1925. This represents a removal of 2 p.p.m. out of 164 p.p.m. suspended solids in the raw sewage.

**The screenings from the New York City Canal St. and Dyckman St. plants are collected and disposed of with the much larger volumes of garbage. This seems to be the most satisfactory means of disposal under the circumstances, but where the wet screenings are dumped in large quantities into an incinerator, as attempted at the Jamaica plant, it has been found to interfere with proper combustion.

Table I

	Removal cu. ft. per m.g.	Moisture per cent	Disposal
Chicago—Des Plaines River	4±*	85	Dumped and buried
Milwaukee	7.5	90	Dumped
Lodi	12	87	
Pasadena	30	88	Buried
Long Beach	40	80	Burned
Los Angeles	16.5	87	Buried

ings satisfactorily. This is by incinerating in a home-made furnace with natural gas supplied by the municipality. Under existing conditions this is an economical and satisfactory method of disposal and one that deserves consideration when cruder methods are unsatisfactory.

Sedimentation Tanks. — In settling sewage it should be discharged from the tank, if possible, before it has a chance to become septic. Therefore contact with decomposing sludge or a long period of detention in the tank is generally to be avoided. Consequently, the plain sedimentation tank with mechanism for the prompt removal of the sludge has come into favor.

In the plants visited plain sedimentation tanks with hopper bottoms are found in one-half of the Des Plaines River Works at Chicago and at the South Side Plant at Houston, Imhoff tanks at the Calumet Works (for pre-settling) and at the West Side Works, Chicago, and at Pomona, and tanks with the mechanical removal of sludge at the North Side Works and the West Side Works (skimming tanks), Chicago, at Antigo, Milwaukee, Lodi, Pomona, Harbor City and Grand Canyon for final settling and at the Chicago North Side Works and the Harbor City plant for pre-settling as well. Tanks of this type are frequently called "clarifiers."

The Link-Belt clarifier consists of scrapers which push the sludge to a sump at one end of a long rectangular flat-bottomed tank. These "flight conveyors" are operated by endless chains on each side passing over sprocket wheels at the end. In their return at a higher level they may also serve to break up the scum or skim off the grease. This device is installed in the skimming tanks of the West Side Works, Chicago, and in the pre-settling tanks at Harbor City.

The Hardinge clarifier resembles the Fidler apparatus found in Germany, in which a spiral scraper rotating slowly in the bottom of the tank collects the sludge to an outlet pipe in the center. This device is to be installed at the North Side Plant at Houston and at Pasadena.

The Dorr clarifier, installed at the other plants employing mechanical removal, is similar to the Hardinge in that the sludge is gradually scraped to a sump or outlet at the center, but there are short scrapers set diagonally on four radial arms in place of a single spiral scraper. By a special mechanism one or more of these arms is automatically extended and withdrawn so as to collect from the corners of a square tank.

Each of the above types of tank has a field of usefulness: the tank with hopper bottoms and the Imhoff tank where their depth is not too costly, the hopper-bottomed and those mechanically cleaned where the sludge can be disposed of while fresh or held to decompose, as in separate digestion tanks, etc. The tanks of the clarifier type appear to be especially adapted to situations where excavation is costly, to final settling in connection with activated sludge or tricking filter plants or where removals of 40 or 50 per cent of the suspended matter is desired within relatively short periods. Sixteen separate digestion plants were installed in the United States in 1927 and 1927.

By digesting sludge the volume is reduced and the product is more readily drained or filtered and is free from objectionable odor. During the process methane gas of good calorific value is given off. By proper control of the acidity and temperature of the sludge the volume of gas may be materially increased. In Germany it has been sold to gas companies, at Birmingham it is utilized for power, and in the United States there are now several plants where gas recovery is an important feature. The largest of these has just been installed at Decatur, Ill., but that at Antigo, though one of the first, is of especial interest on account of its careful design and successful operation in spite of adverse climatic conditions. Gas collection may be used in connection with Imhoff tanks but more perfect control is possible with separate digestion tanks. The gas at Antigo is not utilized except to heat the sludge although a certain excess is available in summer. The gas produced at several plants is as follows (Table II):

Table II

Place	Cu. ft. per cap. daily	Methane per cent	B. t. u. per cu. ft.
Chicago—Calumet	0.4(0.1-1.1)	85	700
Atlanta, Ga.	———	———	700
Birmingham, Eng.	———	67	625-750
Essen-Rellinghausen, Germany	0.3	65-90	785-1010
Decatur, Ill.	.14-.51	70-80	700
Stuttgart, Germany	0.35	75.5	840-955
Antigo, Wis.	0.78	———	656

The amount of gas produced at Antigo is relatively high but in the opinion of the designer, Mr. Jerry Donohue, who has carefully watched its operation, "1 cu. ft. of gas per capita per day is not an unreasonable amount to expect where the design calls for a gas-tight digestor and where no leaks permit the escape of gas about the plant." So far as the above plants are concerned it would be a fair inference that under ordinary conditions at least 300 b. t. u. per capita could be recovered daily which, with coal at 12,000 b. t. u. per lb., would be equivalent to 4½ tons a year for every 1,000 persons. Where the sewage is strong, the cost for fuel is high, and sludge digestion is feasible, the recovery of gas for power, heat or lighting should be considered. The volume recovered will depend on the character of the sludge, being generally greater with strong domestic sludge and increased if mixed with activated sludge maintained at optimum temperatures and pH values and gently mixed by stirring.

Aeration Processes.—Of the plants visited pre-treatment at the Des Plaines River Works, Chicago, at Milwaukee, Indianapolis, Lodi and Pasadena is by fine screening. This includes the three plants where fertilizer is produced as, with the limited percentage of removal of solids desired, fine screens generally take less space and are less costly than tanks. In some situations, however, it is possible that shallow tanks providing a brief detention may be quite as cheap while serving as well for the removal of grease by skimming. At Houston the sewage is merely coarse-screened before aeration.

In the matter of aeration the "Manchester system" of spiral flow is adopted at the North Side Works and in one unit at the Des Plaines River Works, Chicago, at Indianapolis, Pomona and Harbor City, these being in general the newer plants. At Pasadena experiments have shown no advantages in spiral flow, probably due to the narrow width of tank. At Harbor City perforated pipes were adopted in place of diffuser plates for economical reasons in a temporary plant, but with apparently good results. At Pasadena the Norton plate has replaced the Filtros plate used heretofore, being durable and efficient and no more expensive. The experiments in mechanical agitation being conducted at the Des Plaines River Works have not been carried far enough to arrive at conclusions. In view of the very general adoption of diffusion by compressed air in the United States while in England much attention has been given to aeration by mechanical agitation, it is believed that experiment along these lines should be profitable in this country. This is especially the case, as a large part of the operating cost of activated sludge plants is due to the power used for aeration and agitation, while it is admitted that the efficiency is very low, most of the air escaping without change. Efforts looking to a more economical use of air seem likely to result eventually in lowering the cost of power, whether by more effective baffling, by decreasing the submergence of the diffusers, as is attempted at the Des Plaines River Works, Chicago, and at San Bonito, Tex., or by surface agitation.† An element of cost is the area required and as surface agitation implies shallow tanks it usually means a larger acreage which, to that extent, is a disadvantage. Climatic conditions should also be considered in the northern United States,

†Another method, called the "Stream-Flow Process," in which the natural aeration of a shallow stream is simulated, is described by Jenks and Levine on p. 381 of this issue of "Water Works and Sewerage."

where large areas of shallow tanks might present difficulties.

In the plants visited the amount of air required was generally between 1 and 2 cu. ft. per gallon of sewage, the lowest requirements being at Milwaukee (0.95), Calumet (0.9), Des Plaines River (1.25), Indianapolis (1.1), and Pomona (1.3), and the highest being at the two plants at Houston (2.0), and Grand Canyon (about 4). It will be noted that in general plants employing "spiral flow" use less air than those on the "ridge and furrow" system, but the bare figures may be grossly misleading without considering the other uses to which air is applied at the plant, such as for air lift (Grand Canyon, Houston) and sludge filters (Pasadena). The excessive use of air at Grand Canyon is due to the disproportionate capacity of the blower.

A strict comparison of cost between the several plants should also be taken with reserve as locality, size of plant and many other factors enter, but such as have been obtainable are given in Table III.

Sludge Disposal.—The disposal of sludge in lagoons, like the old-fashioned cess-pool, is not always a nuisance and yet cannot be considered ideal or free from possible odor. Where remote from habitations, as at Indianapolis and Houston, it serves without serious objection as an inexpensive expedient.

Prepared sludge-drying beds, as found at the Calumet and West Side Works, Chicago, Antigo, Lodi, Pomona and Harbor City, are less objectionable and with well digested sludge should be fairly free from odor. To prevent the spread of odor from fresh sludge the beds can be covered with greenhouse construction, as tried out at the Calumet plant, but this adds materially to the cost, and although it has generally been found to hasten drying, experience at the Calumet plant does not seem to have realized expectations, except in so far as it has extended the period when drying may be carried on. So far as known, covered sludge beds have not been adopted for any large plant, where sludge handling operations would offer special difficulties.

The success of the activated sludge process depends upon the building up of floc under aerobic conditions. The role of bacteria in the chemical changes that take place, which is generally considered of prime importance, is not definitely known and by some is not considered essential. But where the sludge is to be dewatered the amount and condition of the floc is a matter of vital importance. At Milwaukee the floc was formerly so broken up by centrifugal pumping as to be unfilterable. This was largely overcome by the substitution of plunger pumps. At the Des Plaines River Works, however, but little difference was noted between the filterability of sludge pumped by centrifugal pumps and that pumped by ejectors. A septic sewage is less amenable to flocculation than one that is fresh. In addition to this it is necessary to intensify flocculation by "conditioning" the sludge—that is, to increase coagulation by means of chemicals. For this purpose sulphuric acid has been generally used in the past at Milwaukee and sulphate of alumina at Chicago, but more recent experience at both plants points to the use of chlorinated copperas or ferric chloride. The choice depends in part on the cost and in part on the condition of the sludge. At Milwaukee all three of the above conditioning agents are used in turn, depending on temperature conditions: sulphuric acid in summer and chlorinated copperas in winter. Ferric chloride, tried at the Calumet plant, appears to be yet more effective in producing high rates of filtration but its cost has generally precluded its regular use. To promote filtration and drying, "Filter Cel," a diatomaceous earth, is used at Pasedena. Its effect is purely physical but it is effective in promoting filtration. For eastern plants freight charges would preclude its use, and a further disadvantage is in the dilution of the fertilizing ingredients of the product, "Milorganite" from Milwaukee containing about 7 units of nitrogen as compared with 5½ units in "Nitroganic" from Pasadena.

In the matter of dewatering, the modern Besco-ter-Meer centrifuge was found satisfactory in some respects with activated sludge at Milwaukee but was abandoned on account of the cost and the large amount of fine suspended matter in the effluent that had to be returned for treatment. After experiments with various devices the Oliver filter has been adopted at Milwaukee, the Calumet plant, Chicago, and Pasadena, the Berrigan press at the Des Plaines River Works, Chicago, and at the North Side plant at Houston an American continuous vacuum filter is being installed. By these devices the moisture is reduced to a point between 75 per cent and 80 per cent, so that further drying by heat can be economically carried out.

Table III

	Cost of activated sludge plant construction. Per m.g.d. capacity	Operation‡ per m.g.
Chicago—North Side	$ 97,000†	.....
Chicago—Des Plaines River	252,000††	.....
Indianapolis	40,500	$ 9.73
Milwaukee	99,000	16.80
Lodi	75,000	21.30
Pomona	80,600	25.90**
Pasadena	86,500	67.98**
Harbor City	37,000	.....
Grand Canyon	485,000*	475.60
Houston—South Side	22,000	13.15
Houston—North Side	24,500	17.50

†Exclusive of sludge digestion.
††Including experimental features.
*Including connection trunk sewer and outfall.
**Exclusive of revenue from fertilizer.
‡Exclusive of fixed charges.

††$22.50 (more recently $25.00), including freight charges.

The filter cake is dried in Atlas dryers at Chicago and Milwaukee and in Ruggles-Coles dryers at Pasadena. At Houston Buckeye dryers are being installed. The product from the dryer is ground, sifted and sold at Milwaukee at a net price, exclusive of freight, of of about $15 per ton,†† at Chicago $25 per ton, in carload lots, and at Pasadena $32 per ton, f. o. b. cars.

The manufacture of fertilizer from activated sludge requires considerable capital outlay and careful technical skill as well as educational work in building up a market, but the inherent value of the material is such that the revenue from sales under present conditions should about offset the cost of manufacture where transportation facilities are good and the market not too distant.

Chlorination. — Chlorination of the effluent is carried out at Lodi, Pomona, Pasadena and Grand Canyon, in the first three instances to protect irrigated land from any germs of disease that might survive and at Grand Canyon for the drinking purposes in place of the restricted water supply. The situation in each case is exceptional and the expense of chlorinating an activated sludge effluent from which practically all pathogenic organisms have been already eliminated would not under ordinary conditions be justified.

Uniform License Requirements for Plumbers

Uniform license requirements for plumbers in Bergen County would result in a reduction in building costs, according to M. W. Cowles, sanitary engineer of the Hackensack Water Co., Weehawken, N. J.

"One large item of expense to plumbers is the necessity of securing licenses in each community," Mr. Cowles says.

"In some cases this means the payment of a yearly fee; in others a bond must be deposited in addition. This condition sometimes arises because local plumbers wish protection against craftsmen from other communities where license fees are lower.

"Many builders require competitive plumbing bids, and cost of licenses frequently adds to the expense of the work. A plumbers' examining commission, county or state, would make it possible for any plumber so licensed to work anywhere in Bergen County.

"This would not in any way react unfavorably to the local man, who is in a position to do the work most reasonably."

The water company, Mr. Cowles says, advocates uniformity in plumbers' licenses as part of a generally uniform code of plumbing requirements in the seventy municipalities of Bergen County. Such a code, experts claim, would eliminate unnecessary building expense and safeguard health by requiring conformity to the latest plumbing practice.

Valuation of Public Utilities for Taxation

Impartial and Constructive Sketch of the Fundamentals of the Plan

By L. D. McPHERSON
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THE constant concern of the people about the age-old and ever-present problems of property taxation warrants lively interest and continued discussion of means for improving the distribution of necessary taxation burdens.

Ambitious men are able to so disguise selfish propaganda as to make it appear to the voters that property tax burdens will be shifted to wealthy groups or corporations for whom it is difficult to arouse popular sympathy.

A full and fair discussion should lead the people to a clear understanding that this is a delusion and that it is futile for them to increase the property taxes of such groups and corporations because practically all of such increases will be added to the cost of capital or service which the people must use.

Under the laws of many states steam railroads and other public utilities are subject to ad valorem taxation. This requires a valuation. Under the laws of some states additional consideration must be given to the taxpayers' ability to pay.

In determining the valuation and basis for taxation of all such public utilities such items or elements as original cost, investment in facilities, cost of reproduction new, cost of reproduction less depreciation, capitalization, book value, development costs, going concern or market value of securities, either singly or collectively, should not be given controlling weight.

It is not the purpose of this article to discuss valuation for rate-making or for any purpose other than for taxation. It is here insisted that changes in valuation for taxation should not precede but should follow any changes in valuation for rate-making purposes only after the changed valuation has resulted in a change of rates. Such properties can not have any value which will not vary as their usefulness or capacity to earn varies. The question of the valuation of public utilities for purposes of taxation arises only in states where all property must be taxed on an ad valorem basis. Equity may construe this "ad valorem" value basis to mean commercial as opposed to investment or capital value.

In making a valuation of all such public utilities for taxation, little theory or speculation as to future rates, expenses or other factors should be indulged.

If the profitableness of the operation of such public utilities over a reasonable period of normal years is fairly ascertained, it is good evidence of its value when considered in connection with the prospects for the future and a chance to sell the property and business at a profit. The present and prospective worth of the services of the public utilities to those who will use such services may limit the value of such public utilities. Evidence of the value of such public utilities, whether monopolistic or competitive in character, should be but little, if any, different from evidence required to support valuations of other property. "The worth of a thing is the price it will bring." This embraces all the characteristics of each individual public utility by which it may be distinguished from other property, including relative desirability of ownership.

For taxation purposes the best evidence of the value of any public utility should be the financial results of operation of such public utility's property and business taken as a weighted average over a reasonable period of normal years for the property and business apportionable to the individual state. Before capitalizing the funds resulting from such operations, an interest rate which is high enough to hold necessary capital in the public utility industry should be increased by some percentage, or otherwise, to provide for taxes. Neither the past nor proposed taxes of a public utility should be used in the calulations. One step in the calculation might be to use the ratio of the general property taxes to the market value of general taxable property other than that of public utilities. For example, if it may be assumed that: (a) six (6%) per cent is an adequate interest rate; (b) the rate of general property taxes is $3 per $100 of assessed value; (c) general property is assessed for taxation at fifty (50%) per cent of market value, it follows that the six per cent for interest should be increased by one and one-half (1½%) per cent for taxes, making seven and one-half (7½%) per cent the factor by which to divide said funds to ascertain the approximate value of a public utility.

The justification for resorting to the methods of valuation herein discussed may not be found to exist as fully in the case of purely local monopolistic public utilities such as municipal water plants, local gas companies or in condition where contract ordinances fully define and provide for valuations for specific purposes.

Any method of valuation of public utilities for purposes of taxation should be flexible enough to provide equitable adjustment for, among other things, the following:

(a) The precentage, if any, of their net income which has been fixed as due the state by law.

(b) The part, if any, of the state's tax fund, which has been derived from payments made by a public utility, when such contribution to said fund partakes of the nature of a forced subsidy by the utility to the payment of interest or amortization of principal on public bonds issued or assumed for construction or other aid to competing public or semi-public facilities.

(c) Relative advantages and disadvantages accruing to public utilities, or their competitors from recent advancement in the arts, or obsolescence in the facilities of either, when the services, or cost thereof, as performed by either is thereby affected.

Public utility valuations are made for various purposes. These valuations are used by various boards and commissions. For example, the Board of Equalization of the State of Montana is obliged to fix valuation of railroads within the State of Montana for taxation purposes. They have had several different methods suggested as to the proper way of arriving at such value and are giving earnest consideration to the suggestions for the purpose of determining which method is fair to the railroad companies as well as to the state.

In Montana the railroads pay an ad valorem tax. They do not pay, as in some states, a tax based upon their gross revenues within the state, but, in addition to the ad valorem tax they pay a corporation license tax of one per cent of their net proceeds derived from their business transacted in Montana.

The Supreme Court ruling in the O'Fallon case is another example of the use of public utility valuations.

The accompanying article by L. D. McPherson, a valuation counsel, presents a method of valuation of public utilities for taxation purposes.—Editor.

(d) Whether or not the state reserves to itself the exclusive power to tax the public utilities.

(e) The extent to which the valuation of property used in unregulated business as fixed for taxation varies from the fair market or service value of the same.

(f) The extent to which unequal taxes of public utilities affects the cost to them to finance expansions of facilities.

(g) The probabilities that

1. Rates of the public utilities for services are on an approximately permanent level;

2. Volume and classes of their business will continue substantially uniform for a few years.

(h) The honesty, economy and efficiency of the control and management of the public utility.

(i) Expediency, or economy of administration by taxing authorities (comparative cost of collection of the state's revenue at other sources). By preventing the undue shifting of the burdens of taxation from other property to public utilities, state taxing authorities will avoid usurping the duties and powers of state and federal authorities in regulating rates and services.

Ascertaining the financial results of operation of public utilities depends upon accounting and involves the whole responsibility of their control and management.

When the state's revenue is at stake no presumption will be indulged. It may be assumed that all reports, returns, records, vouchers or other documents made or kept by the public utility for its own information or required by law and regulations, state or federal, can by law be made available for, and admissible in, evidence in a hearing on taxation. With broad inquisitorial powers vested in public authorities, officially prescribed accounting for capital expenditures, operating and other receipts and disbursements may be so enforced as to reveal the financial results of operations. It is possible that a restatement of the accounts of public utilities may be required to determine whether or not the revenue has been so handled, for the accounting period adopted for making the valuation, that all changes in tangible property and the financial results of operation would be analyzed in such detail as to afford an accurate basis for a just determination of the profitableness or usefulness of the public utility.

The public utility property, or a distinct or separate unit thereof, for which honest, economical and efficient management can show no financial results of operation, which are beneficial to the owners thereof, should be taxed on no higher than a scrap or salvage value, plus the cost to the state, or its subordinate agencies, of whatever services there is required to be rendered it, including fire, police and other protection. If such public utility become so impressed with the nature of a communal facility, it would thereby be entitled to relief from taxation to this extent.

Apportionment.—If the entire public utility is correctly appraised, there remains the difficulty of apportioning the value of interstate public utilities to the several states served. Danger of duplication always exists because each state within its own realm is independent of every other state. The hardship of decisions which do not eliminate this chance of overlapping is not easily relieved by review, because no evidence will more than tend to prove the portion of the total due to an individual state.

In apportioning, judgment should be influenced by a fair consideration of, among other things, the relative importance, both within and without an individual state, of:

(a) Total units of service facilities involved, such as mileage, and classes thereof, of all lines of railway tracks, telephone, telegraph, transmission and trolley wires, pipes, sewers, conduits, aqueducts, toll roads, including the necessary appurtenances and accessories of each, such as:

1. Land for sites for all such facilities;

2. Substructures, superstructures and equipment of shops, engine houses, power houses, transformers, pumping and relay stations, tunnels, bridges, reservoirs, containers, elevators, warehouses, wharves, docks, office and other service buildings.

(b) The number of units of service performed, such as mileage, per ton, engine, train, truck, taxicab, van or omnibus, car, passenger, crew, loaded and empty movement; cubic feet of natural or artificial gases; kilowatthours of electricity; gallons of water, oil or other fluids; number of messages, local and long distance, direct and reverse charges on same, etc., including distances, elevations, curvature or other resistances involved.

(c) The extent to which the services performed by the public utility is monopolistic or is being dispensed with by potential patrons resorting to competing substitutes.

(d) Volume, density and classes, as well as the seasonableness or fluctuations therein of local, through and interline business originated, on, handled over or delivered by the various branches, separable units or trunk line facilities in the several states, the relation of each to the individual public utility's total business and the relative desirability to such public utility of all business transacted.

(d) Whether or not the lines or facilities are branches or auxiliaries, which are only capable of originating business requiring further processing of unfinished products or services for which intervening services by a trunk line are indispensable to the collection for services.

(f) Relation of the actual service demanded of and performed by the public utility to the capacity of the facilities which it must own or control.

(g) Climatic and seasonal disturbances which affect operation and maintenance.

(h) Operating ratios; revenue collected; expenses and damage claims paid.

(i) Fixed rentals paid for use of facilities in the several branches of the service and in the several states.

(j) The relative amount of reserves impressed with obligations for replacement, depreciation, amortization or other sinking funds applicable to the facilities owned or leased in the several states or different branches of the service.

(k) The nature and amount of the liens or other encumbrances, on the parts of the property in the several states or different branches of the service.

Property not used by public utility in the performance of its services to the public, but which is being held for investment or objects not directly connected with such service, should be valued separately from its operated property and taxed on the same basis as if owned or used in unregulated business.

If an easier way, which is just and equitable, can be found to value steam railways and other public utilities for purposes of taxation, it should be adopted.

Ground Water in Southern Idaho

An investigation to determine the geology and underground water resources of the Snake River lava plain, in southern Idaho, has been carried on since May, 1928, by the Geological Survey, Department of the Interior, in cooperation with the Idaho Bureau of Mines and Geology, Idaho Bureau of Reclamation, North Side Canal Co., Twin Falls Canal Co., Minidoka Irrigation District and Idaho Power Co., under the general direction of Harold T. Stearns. The region studied covers over 16,000 square miles. Maps have been prepared showing the direction of movement of the ground water under this vast plain, also the location of the wells from which the measurements were obtained. Many interesting conditions are shown by the ground-water contours — for example, near Idaho Falls, where the ground water is moving westward toward the heart of the desert instead of southward with the slope of the ground surface and the Snake River. These maps are now open for public inspection in the Geological Survey office at Room 232, Federal Building, Idaho Falls, Idaho.

Management and Operation of a Water Works System

General Outline of Methods of Operation at Ottawa, Ont.

By W. E. MacDONALD
Water Works Engineer, Ottawa, Canada

BY instituting a bureau of purchases and supplies it has been found possible to effect substantial savings in the purchase of material and supplies. Requisitions for goods from time to time are made to the purchasing officer in charge of this division and by planning the work, where possible, well in advance, purchases can be made in quantities and when advantage is taken of the low prices that prevail during certain periods when the manufacturers are over-stocked substantial savings may be effected, provided adequate and well located storage space has been arranged for.

Pumping Stations.—In recent years, many factors have largely been responsible in changing the trend of pumping practice. Probably one of the most important changes wrought has been the introduction of the centrifugal pump, which has become a serious competitor of the reciprocating steam engine driven type. The extended use of electricity has witnessed the installation of electrically driven centrifugal pumps as a moderate and convenient means of handling large and small quantities of water under almost every conceivable condition.

In Canada the difficulties of operation in winter through the formation of frazil ice have been greatly lessened by the use of revolving screens combined with the application of steam.

Distribution System.—The distribution system should be designed that it will be capable of supplying adequate quantities of water throughout the entire district for domestic and commercial purposes as well as for fire extinguishment. The cost of a distribution system is usually the largest expenditure of any water works and consequently great care must be taken in both the original design and the extensions as required from time to time.

The planning of a water works distribution system with respect to improvements looking to greater efficiency and more production, is a matter that must take into consideration not only immediate results, but also requirements of the future, when growth and extension of the municipality will call for greater facilities.

New Main Extensions.—In many cities throughout Canada the frost penetrates into the ground for a depth of from 4 to 10 ft. below the surface, necessitating installing mains in many cities west of Winnipeg, with a minimum covering of 11 ft., to prevent mains from freezing. It is important that the engineer should have definite knowledge in advance of the frost penetration in various grades of soil in his own municipality to permit of the mains being installed with a minimum of covering to safeguard freezing, yet avoiding an installation at too great a depth incurring an unnecessary cost.

In regard to the construction work carried out by the city of Ottawa in connection with new water main extensions, where a minimum average covering of 7 ft. is necessary, allow me to set forth the procedure that has been established. When it is proposed to make extensions the engineer in charge has a report prepared with estimates and detailed plans showing the cost of construction, the required revenue and the estimated revenue from the property served by the extension. The work having been duly authorized, the engineer then selects the most competent foreman, and issues an official work order, to which is attached a blue print setting out the new extension, giving the location of all valves, hydrants and specials. These work orders made out in triplicate, contain detailed instructions to the foreman and state definitely the amount of material he is permitted to requisition from the corporation stores. The effect of these orders is to only allow the foreman to receive from stores, the exact amount of material contained in the engineer's estimate and thereby tends to economy. Upon completion of the work, all material and labor is entered on the order and all changes and installations are indicated in red on the blue print and returned promptly by the foreman to the draughting office where a permanent record is made.

Unit Costs.—In addition, the department requires the foreman to make, each day, a complete report of the day's operations which include the following items: The cost of the work performed each day, complete cost to date, materials used each day, and a complete summary of work carried out to date. From these reports the department completes its records in detail, which are submitted to the engineer, and from which he is at once able to make an analysis of the unit costs of all foremen. The effect of these records greatly increases the efficiency of the foremen who soon realize that a permanent record is maintained of their work.

Care in Main Laying.—In the past there seems to have been a tendency to use less care in the construction of the distribution system than was exercised in the construction of any other part of the water works system. This may have been due to the fact that the work was soon covered and out of sight, or from previous lack of experience in good construction practice. Whatever the reason, it has resulted in the development of much trouble often occurring at the most inopportune times and resulting sometimes in heavy property damage and loss of life. Having a previous knowledge of all this the city of Ottawa is most careful in the installation of all mains and services. In this respect I might say that all cast iron pipe gate valves meters and special pipe castings are subject to a standard hydrostatic test before acceptance and must be certified as having satisfactorily met these requirements by one of the official inspection companies. In addition to this as a secondary precaution against the possibility of trouble developing later, the resident engineer is required to see that all pipes and fittings are properly in alignment in the trench, sufficient supports and necessary tie rods in place. When this condition is satisfactory, the pipe must be filled with water and the pressure raised to permit of an examination for any defects previous to allowing any backfilling of trench.

Protection from Frost.—In many Canadian municipalities owing to extreme cold weather conditions in service and main laying it is not always possible to secure sufficient depth of covering to prevent freezing. For example in the following types of construction, where pipes are suspended across rivers, supported on viaducts, intersect subways and tunnels, it is absolutely necessary, in order to secure protection from frost, to have all such pipes and fittings properly insulated.

Insulation.—During the past 15 years the city of Ottawa, like many other Canadian municipalities, has experienced considerable trouble through interruptions to its service with the resultant damage and monetary loss through the freezing and bursting of many large water pipes and valves. This trouble has invariably occurred

during the coldest winter weather, sometimes when the temperature has been as low as 30 degrees F. below zero. To prevent the re-occurrence of this experience the engineering department of our city now insists on that all water pipes, valves and fittings exposed to freezing temperature must be sufficiently insulated against cold to prevent damage by freezing.

Various forms of insulating experiments have been carried out by the department during the past few years but probably the best protection has been secured from the following method:

The pipe itself is wrapped with one layer of hair felt 1 in. in thickness and secured to the pipe with a wrapping of heavy jute twine at 2-in. centers. Over this is applied one layer of heavy asphalt saturated felt secured in place by the wrapping of jute twine. This process is repeated in its respective order until four complete wrappings have been made. On top of the fourth layer of hair felt is placed a close winding of special electric insulating tape to hermetically seal the joints, and when this is finished it is given a treatment of asphalt compound. The insulated pipe is then wrapped first with oiled paper and an additional lining of heavy rosin sized paper. To protect this insulating material against weather conditions the whole is finally enclosed in a jacket of 8 oz. canvas which is treated with a heavy coat of glue sizing and then with two coats of first quality white lead and linseed oil paint.

Maintenance of System.—There are few works which require greater care and more constant vigilance on the part of its employees than does the operation and maintenance of a public water supply. Under the operation and maintenance division there must be considered the following appurtenances: inspection and maintenance of fire hydrants, valves and meters, prevention of electrolysis, regular and systematic survey for the detection of leaks, thawing of frozen services and finally the efficient handling of all general and emergency repairs to the system throughout the 24 hours each day.

Fire Hydrants.—The proper functioning of fire hydrants in all municipalities is a factor which should receive utmost consideration from the authorities in charge. In this connection let me state that I do not consider it good business to pay out, annually, huge sums of money to maintain an efficient fire brigade unless the water works department is maintained on an equally high standard of efficiency.

In Canada particularly, it is necessary to see that fire hydrants are correctly installed to insure proper functioning in service at all times. In the installation of fire hydrants it is highly desirable to see that all lateral connections are equipped with special control valves and laid at a sufficient depth below the frost line to prevent freezing. The hydrants themselves should be plumbed, well set and provision made for drainage through the adjacent sewer. If the foregoing practice is rigidly followed it will be found that the trouble through freezing will be greatly minimized.

However, in many of the most northern Canadian cities, especially with regard to previous installations, it is necessary, during the freezing period that all fire hydrants be inspected at regular intervals. In Ottawa we find it necessary to examine all hydrants in the business area every 24 hours, while the hydrants in the residential sections are inspected every 48 hours. Perhaps one of the most efficient methods of ensuring that this hydrant inspection is properly carried out is to insist on the inspectors marking, in chalk, on the hydrant, the date of inspection and the letter "A" or "P," indicating morning or afternoon. When making the next inspection these chalk marks are effaced by the inspector and the new time and date again indicated in chalk.

Gate Valves.—One of the most important items and one which very often receives but slight attention, is the proper location and maintenance of gate valves. In the city of Ottawa at every opportunity and especially previous to laying of new pavements the department installs sufficient additional valves to decrease the sectional shut down so that at any time it will not be necessary to close down more than one city block. All gate valves are installed in chambers and are inspected at least annually, for the detection of gland leakage and to ascertain if they are in proper working order. At such times the stuffing boxes are packed, gearing lubricated and a test made to determine that the valve is fully open.

Meters.—The sale of water through meters has become now nearly a general practice, resulting naturally in a rapid increase in the number of meters in service, and requiring increased attention be given to their proper care and supervision.

In Canada to date the full benefit of the metered system is not fully apparent as few of the municipalities are 100 per cent metered. However, practically all of the Canadian cities have realized that the selling of water by measurement is the only equitable way and they are rapidly endeavoring to organize this important branch of the service on a proper basis with a view to increasing the number of metered services.

To successfully carry out a meter program in the city of Ottawa, we have built up an organization as a separate branch of the service whose duty it is to test, install, read, repair and systematically record the individual performance of all meters. The records established by this branch of the service have been of inestimable value to the officials of the department in properly administering its affairs in selecting and purchasing the highest quality of meter and in addition, allowing the superintendent to maintain an accurate check on all services so that the water works department is assured of all income justly due.

Electrolysis.—The city of Ottawa has not been greatly troubled by electrolysis owing to the fact that all returns from the street railway power lines have been grounded to the cast iron distributing header. The effect from this has greatly minimized the trouble from this source.

Detection and Prevention of Water Waste.—The problem of reducing the waste of water which invariably occurs in all unmetered cities and towns should receive an amount of attention, from engineers and water works officials, equal to that formerly given to the problem of securing additional supplies, when the demands for water bid fair to exceed the capacity of the source in service.

The three methods most effective in reducing wastes in the city of Ottawa have been as follows:

(a) Regular inspection.
(b) Waste water surveys.
(c) Installation of meters.

It has been found that a large percentage of the careless waste in buildings from defective plumbing and fixtures can be controlled by a systematic interior building inspection by competent and specially trained inspectors in uniform. The work of these inspectors is rigidly backed up by the department and all consumers must maintain the plumbing in a satisfactory condition, otherwise, failure to do so will result in the supply being temporarily discontinued.

In many Canadian cities, contrary to the prevailing practice found in the United States, it is quite common to have the peak consumption occur during the coldest winter months rather than in the warmest months of the summer season. This unusual condition is brought about by the consumers allowing the water to run to waste to prevent freezing. This condition of waste is not one which should be tolerated or accepted in any city as a solution of the cold weather problem of freezing. An effective method of overcoming this extravagant waste has resulted from the work of our uniform waste water inspectors covering the entire city during the cold weather period and reporting to the engineering office all consumers found running water to waste to prevent freezing. On the receipt of the information, the owners are informed by letter that this unnecessary waste of water must cease and that the pipes and fittings must be protected and insulated against cold. These notices usually allow the owner a period of time not exceeding six months to comply with this regulation. The efficacy of this work is well worth while, as demonstrated by the fact that during the past three years we have re-

duced our daily average winter consumption by more than 2,000,000 gal.

The determination of underground leaks and their ultimate repair is a work which occupies considerable time and in the larger cities is best handled by the organization of a separate pitometer branch of men specially trained in this work. As a great deal has already been written on pitometer operations I will not attempt to elaborate on them here, but will state that my personal experience has been that the results of these surveys is wholly dependent upon the initiative and the efficiency of the operator in charge.

Of all means for the reduction of waste there is none more beneficial for securing results than the introduction of high quality meters and all water departments are well advised in working towards a hundred per cent metered supply.

Thawing of Frozen Services.—Until a few years ago probably one of the most vexing questions confronting the officials of a Canadian water department during the winter months, was the freezing of service pipes. The city of Ottawa, during the extreme weather conditions, probably was affected with more frozen services than any other city on the Continent. There have been winters in Ottawa when services of more than three thousand consumers have been frozen and the department in years past was unable to cope with this situation with the result that many hundreds of families in previous years were without water for many weeks at a time. Like all other water works problems requiring action the city of Ottawa took hold of this situation in 1919 and discontinued thawing services by the former unsatisfactory transformer method and designed and constructed four self-contained electric thawing apparati. The success of these new machines has been truly marvelous in rendering a prompt and efficient public service as well as having reduced the cost of each thawing operation from $6.05 per service to $1.78 per service; effecting an individual saving of $4.27 per service. Allowing for all operating costs, interest and depreciation, the thawing machines have been directly responsible in effecting a saving, during the past few years, of $23,000.

I might say that the city of Ottawa has carried on a program of lowering and insulating where necessary, many services where continual trouble from freezing was experienced in the past and this work, together with the new machines, has done much to lighten the burden of the water department during the winter months.

Keeping the Finger on the Pulse of the System.—To definitely insure the service of the department being efficiently maintained at all times during the 24-hour period we have inaugurated in Ottawa, a central headquarters bureau. The purpose of this office is to co-ordinate all the various branches of the water department. At this office all complaints are received and the officer in charge is continuously informed of the working of the entire department, receiving hourly readings of gauges from the pumping stations, transformer stations, and filtration plant as well as pressure gauge readings from all city fire stations. This office is equipped with fire alarm gong, automatic pressure gauge and furnished with a complete set of plans and blue prints of the entire distribution system, giving exact location of all mains and valves.

Emergency Service. — Emergency service is a most important part of the water department's responsibility in safe-guarding the lives and property of the citizens, and the city of Ottawa has placed this service directly under the central headquarters office. To meet this situation we have specially trained employees operating two emergency trucks completely fitted with all supplies and appurtenances. As a means of assistance in controlling breaks within a minimum of time we have had erected at every intersection in the city valve location plates, giving definite information as to the size and location of each valve. These plates have been of great value, especially in the winter season when it is quite usual to have several feet of snow over many of the valve covers.

Confidence Through Publicity.—Municipal officials can make the work of their departments far more effective by taking the public into their confidence. This can best be accomplished by a judicious use of publicity through the daily press in both its editorial and advertising columns; by assuring the public of the safety of the supply; by the encouragement of the citizens to visit the water works plant; and by seeing that the visitors are made welcome, shown over the plant and intelligently advised as to its workings. At all times see that the public are well informed on the services you are performing, for even though you may consider your local organization ideal, the citizens will not consider it so unless you have the press support back of it.

Acknowledgment.—The foregoing is an abstract of a paper presented at the Toronto Convention of the American Water Works Association.

State Sanitary Engineers to Meet in Chicago.—The next meeting of the Conference of State Sanitary Engineers will be held in Chicago, Ill., on Oct. 13, 14 and 15, 1928, with headquarters at the Hotel Stevens. Arthur P. Miller, Butler Bldg., 3 B St., S. E. Washington, D. C., is secretary-treasurer.

London Water Supply

Notes on Chlorination, Prefiltration and Double Filtration

The 23rd annual report of Sir Alexander Houston, head of the water works of London, England, covering the year ended Dec. 31, 1928, is summarized in a recent issue of The Engineer, from which the notes following are taken:

Chlorination of Thames Water.—The period covered by the report is the 13th year during which Thames water has been dealt with by this process. Never since it was begun in 1916 has there been a single instance of complaint as regards taste, though some 76 million gallons are treated every day and some 2,000,000 consumers are each supplied with an average of 38 gal. per day each. Apart from a large saving in coal consumption, since pumping into reservoirs is to a considerable extent lessened, there has, since the introduction of chlorination, been a marked increase in the number of million gallons of water filtered per acre of filter beds cleaned. In the worst case—that of Kempton Park—the increase was from 28.1 to 31.47 millions, and in the best—at West Middlesex—from 35.25 to 67.40, a rise of 32.55. As it costs some £40 to clean an acre of filter bed, it will be realized that the saving that has been effected is very considerable.

During the year an up-to-date liquid chlorine plant, installed at Hampton, took the place of the last remaining chloride of lime plant for chlorination on the board's works. A new factor, too, was the utilization of raw Thames water from the Staines Aqueduct for filtration on the Southwark and Vauxhall filters at Hampton. The water was drawn from the aqueduct at the outlet to the Littleton Reservoir, and passed down the Littleton conduit to Hampton, a special chlorination plant being erected at the Littleton outlet to deal with it. The average dose applied, in terms of available chlorine, was 0.42 part per million. The average cost of chemicals per million gallons treated worked out at 8.8d.

Chlorination of the New River.—Normally, the New River is only chlorinated during the winter months when the water deteriorates considerably in quality, owing, chiefly, to floods, the deficiency of storage accommodation, and, to some extent, to the filtration area being hardly adequate in size. Hence, although the annual reports are now based on the calendar and not the financial year, it was considered advisable that the period covered by the report should be from November, 1927, to March, 1928. Sir Alexander reports that the results obtained were rather remarkable. One hundred and four samples collected at Highfield, before chlorination, contained B. coli in 1 c.c. —or less—in 68.3 per cent of the sam-

ples examined. The same number of samples collected at Wood Green, after chlorination, contained no B. coli in 100 c.c.—or one hundred times as much water—in 85.6 per cent of the samples examined. At the outlet from the Hornsey reservoir the results were practically the same, no B. coli were found in 100 c.c. in 84.6 per cent of the 104 samples. The main point is that the effects of the winter floods, as shown above Highfield, before chlorination, are practically effaced, in a bacteriological sense, by the chlorination process at that station, so that when the water reaches Wood Green it is literally transformed in quality."

It may be added that the total cost of the chemicals used in the New River treatment was £520.54, or at the rate of 1s. 10.8d per million gallons treated.

Pre-Filtration Waters.—Since 1922 all the various kinds of water which "feed" the filters, and which are known as pre-filtration waters—raw water, stored water, gravel water—have been completely and thoroughly examined, chemically and bacteriologically, each week. Sir Alexander remarks that he "feels that the pulse of the metropolitan water supply is the condition of the pre-filtration waters," and he derives some most interesting information from these examinations. For example, he finds that there is an enormous improvement in the bacteriological quality in the raw Thames, Lea, and New River waters, consequent on storage. As an instance, he points out that as raw Thames water contained B. coli in 57.7 per cent of the samples in 0.1 c.c. —or less—and as Chelsea stored water contained B. coli in 100 c.c. in 57.6 per cent of the samples, it might be said that Chelsea stored water was improved 1,000 times. Indeed, from the figures adduced, it is seen that nearly all pre-filtration waters are improved from 100 to 1,000 times as compared with the raw river water. Moreover, it is impossible to store river water without certain physical and chemical changes taking place, and it is possible to read into these alterations of composition, indirect, but valuable evidence of what has taken place bacteriologically. It takes time to effect these physical and chemical changes just as it requires time for the destruction of pathogenic bacteria in water under conditions of storage. From the figures in the tables given in the report, it is obvious that the raw waters are, generally speaking, altered considerably in character by reason of storage, and that the percentage reductions for the various tests are not uniform, the tendency being for the ammoniacal nitrogen, turbidity, and color tests—especially the first two — to show proportionately greater reductions than the albuminoid nitrogen and permanganate tests.

The Barn Elms Experiments.—What are known as the Barn Elms experiments were instituted some years ago to test the effects of passing water, which had previously been treated in primary filters, through an ordinary sand filter at rates up to three times the customary London rate, which is rather less than 2 gal. per square foot per hour. For the purpose, the outlet of one of the filter beds was altered so that this increased rate of flow could be obtained. The chief questions which it was sought to answer were:

(1) Would the filtrate from the altered bed compare favorably, or unfavorably, with the filtered waters generally, as judged physically, chemically, and bacteriologically?

(2) Would there be an increase, or a decrease, in the "number of million gallons filtered per acre cleaned?"

(3) Would there be any evidence of a gradual, but progressive blocking of the interior of the filter, resulting in "the number of gallons filtered per acre cleaned" becoming less and less as time went on?

An adverse verdict regarding No. (3) would mean that practically the whole bed would have to be turned over and cleaned periodically, as, indeed, is the custom at some works of the board. In such a case, everything would depend upon the extent of internal blocking as a result of the "rushing" filtration tactics. So far as the test has been carried, it does not appear, according to the report, that any progressive interior choking of the bed is foreshadowed. Furthermore, as the result of about 52 months' experience, it would seem that the following results can be obtained, assuming comparable conditions, by the methods employed at Barn Elms:

(1) A final product practically as good, on the average, as that resulting from the ordinary slow filtration process.

(2) Comparative freedom from algal troubles, or those caused by an excess of suspended matters, owing to the useful work carried out by the primary filters.

(3) A considerably greater output of water per acre of filtration area, allowing for the space covered by the primary rapid filters, per unit of time.

It may be added that the primary filters have been worked at an average of 141 gallons per square foot per hour, while the experimental filter has been worked at an average of 4.42 gallons per square foot per hour, and has yielded 75.1 per cent of first-class samples, i. e., no B. coli in 100 c.c. water.

Walton Works.—At the Walton works rapid filtration is followed by a filtration, at considerably more than the usual rate, through ordinary sand filters. Raw Thames water is first stored in Walton reservoirs, then filtered — without coagulant — through eighteen primary filters, working at the average rate of 112 gal. per square foot per hour. The next process is filtration through secondary filters working at the average rate of 5.61 gal. per square foot per hour. Finally, the water is chlorinated, the average dose being 0.207 part per million.

The results obtained, as set out in the report, are as follows:

Bacteriological (Average) Results

Number of Bacteria in Agar at 37 deg. C. per c.c.

A. Raw river water.....275
B. Walton stored water..... 15
C. Mixed filtrates from one set of primary filters 18
D. Mixed filtrates from other set of primary filters 21

Filtrates from the Six Secondary Filters Before and After (in brackets) Chlorination

E. No. 1 Filter.....2.8 (2.7)
F. No. 2 Filter.....5.4 (4.3)
G. No. 3 Filter.....3.3 (2.7)
H. No. 4 Filter.....5.8 (4.3)
I. No. 5 Filter.....3.4 (2.9)
J. No. 6 Filter.....5.3 (4.9)
K. Final filtrate from the general filter well (mixture) of all the chlorinated waters 3.7

Percentage Number of Samples Containing No. B. Coli in 100 c.c. (First-class Samples)

The results are given in the same order as in the foregoing:

A. 0.0 (91.6 per cent contained B. coli in 1 c.c. or less).
B. 34.5.
C. 45.0.
D. 51.4.
E. 92.3 (99.1).
F. 89.9 (100.0).
G. 83.2 (98.1).
H. 89.1 (100.0).
I. 93.9 (99.1).
J. 76.3 (93.5).
K. 96.4.

It is explained that the results, as regards A, B, C, D, and K are for the calendar year 1928. The results for E to J are for the period Jan. 1 to Nov. 9 inclusive; afterwards the place of chlorination was altered to allow for the addition of ammonia before chlorination, the mixed water from all the filters being chlorinated at one spot, before going to the general well.

"Bacteriologically, it would be hard to surpass these results," remarks the report. "To change a water containing B. coli in 1 c.c. in 91.6 per cent to one yielding no B. coli in 100 c.c. in 96.4 per cent of the samples examined is a striking feat."

The report gives much further interesting information regarding these works, and the experiments made with the filters, as well as several further tables. We can, however, only spare space to quote the final paragraph in this section: "In looking through these results many items catch the eye; for example, the very high rate of filtration in the case of the primary filters (112 gal. per square foot per hour). The high rate of filtration through the secondary filters (5.61 gal. per square foot per hour), having regard to the much lower rates commonly employed. Finally, the remarkably high number of million gallons filtered per acre cleaned (576 m.g.)."

Equipment for Electrically Driven Pumping Stations

A Method of Improving Operation and Securing Economy at Low Cost

By R. L. BALDWIN

Of Burns & McDonnell Engineering Co., Kansas City, Mo., and Los Angeles, Calif.

MANY small cities have direct pressure systems for water supply. Where steam driven pumps are used it is possible to vary the speed in proportion to the quantity of water required thereby maintaining an even pressure.

Where motor-driven units are in use it is difficult to maintain constant pressure since the motor speed of standard equipment is constant. This means that pressure must vary with the discharge and that unfortunately when more pressure is required at high rates of discharge to compensate for friction losses, it is low or inadequate. Such installations are, therefore handicapped with poor pressure regulation. High pressures must be carried at times when not needed in order to have an adequate pressure when large capacity is required. This in turn causes poor over-all efficiency, often being from 30 per cent to 40 per cent, and even less.

Where it is possible the installation of elevated storage on the system solves this question and adds many other advantages. At the outset, the writer wishes it understood that the method of operation proposed in this paper is not a substitute for elevated storage, but that it does give a method of improving operation and economy at low cost and may serve in many cases where the use of elevated storage is not feasible. The paper is an application of the automatic method of operation to the pumping of water with particular attention being paid to improvement of economy.

The Motors.—The use of a variable speed motor may serve in some instances to drive a pumping unit and obtain reasonable efficiency. If a slip-ring motor is used, resistance must be used to obtain reduced speed. Ordinary operation must be at the reduced speed in order to have increased capacity at higher speed for peak demands. This means a high energy loss in the resistors in order to obtain this speed control and a corresponding low efficiency.

A motor of the brush shifting type offers good efficiency at all speeds but it has serious speed limitations. The manufacturers have not encouraged its use for such service. Up to this time such a system has not been found economically feasible.

The use of pole changing devices for the variation of motor speed for this purpose causes too great a change in speed at each change. It has been used in some installations but is not generally suitable for a direct pressure system.

Boosters.—Boosters are often used where an increase in prassure is desired for short periods. In the ordinary system it is desired to maintain a satisfactory pressure on the distribution system. Very often a transmission main is required to convey the water from the pumping station to the distribution system and this involves high friction losses at times of maximum discharge. Boosters when used are usually designed for a fixed discharge and pressure to care for the maximum discharge and pressure desired.

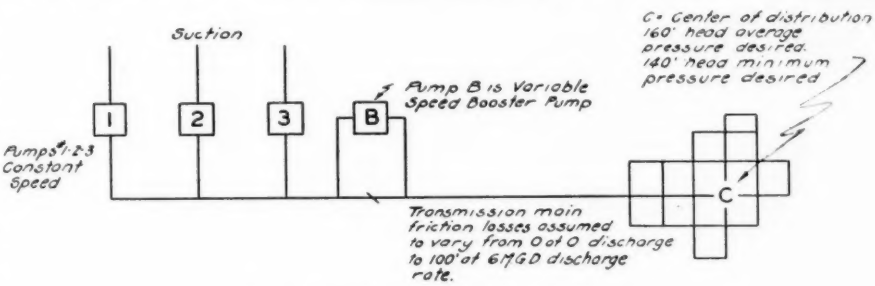

Suction
C= Center of distribution
160' head average pressure desired.
140' head minimum pressure desired
Pump B is Variable Speed Booster Pump
1
2
3
B
Pumps 1-2-3 Constant Speed
C
Transmission main friction losses assumed to vary from 0 at 0 discharge to 100' at 6 M.G.D. discharge rate.

Fig. 1—Layout of Assumed Pumping Station

Another method might be used, namely, two or three ordinary centrifugal pumps driven by constant speed motors with a booster of variable capacity and pressure designed to take care of friction losses. In this way the base load pumps could be operated at a maximum efficiency and the low efficiency would be on the booster pump alone. At low rates of discharge necessitating low speeds, the efficiency of the booster would be low but it would carry only a small portion of the load and hence would not affect the overall efficiency much. At the high rate of discharge when the friction is increased and becomes a larger portion of the total load, then the higher speeds are required and the overall efficiency is better.

Assumptions.—In order to determine the overall economy of pumping with such an arrangement, a case has been assumed where it is desired to maintain a pressure on the distribution system of approximately 160 ft. head and not less than 140 ft. head. The friction loss between the pump station and the center of the distribution system has been assumed to vary from zero at no load to 100 ft. head at the maximum rate of discharge.

Operation on the flat portion of the head capacity curve for a centrifugal pump means fairly constant pressure, but the range of constant pressure operation with a single pump and with reasonable efficiency is very limited. Hence it is wise to use at least three units as they may be suited to the load more closely. An average pumpage of between 2 and 3 M.G.D. is assumed and standard single stage centrifugal pumps designed for heads and capacities as follow are used:

Pump No. 1	1 M.G.D. at 160-ft. head,	50 hp.,	1,800 r.p.m. motor
Pump No. 2	2 M.G.D. at 175-ft. head,	75 hp.,	1,800 r.p.m. motor
Pump No. 3	3 M.G.D. at 160-ft. head,	100 hp.,	1,800 r.p.m. motor

The second is designed for a slightly higher head to take care of friction losses as it is desired not to connect the booster until more capacity is needed. The booster can use a standard centrifugal pump driven by a wound rotor motor of 125 hp. capacity, 1,200 r.p.m. With the friction losses at various rates of discharge known a pump can be selected so that it can be operated to exactly absorb the friction losses by varying the speed of the motor as required.

All of these pumps and motors are standard pieces of apparatus and their operating economy can be readily obtained at various loads and speeds. Reference to Fig. 1 shows diagrammatically the assumed layout. Figure 2 shows curves giving the characteristics of the booster pump at different speeds. These same data for the constant speed pumps are given in Fig. 3.

Method of Control.—By proper selec-

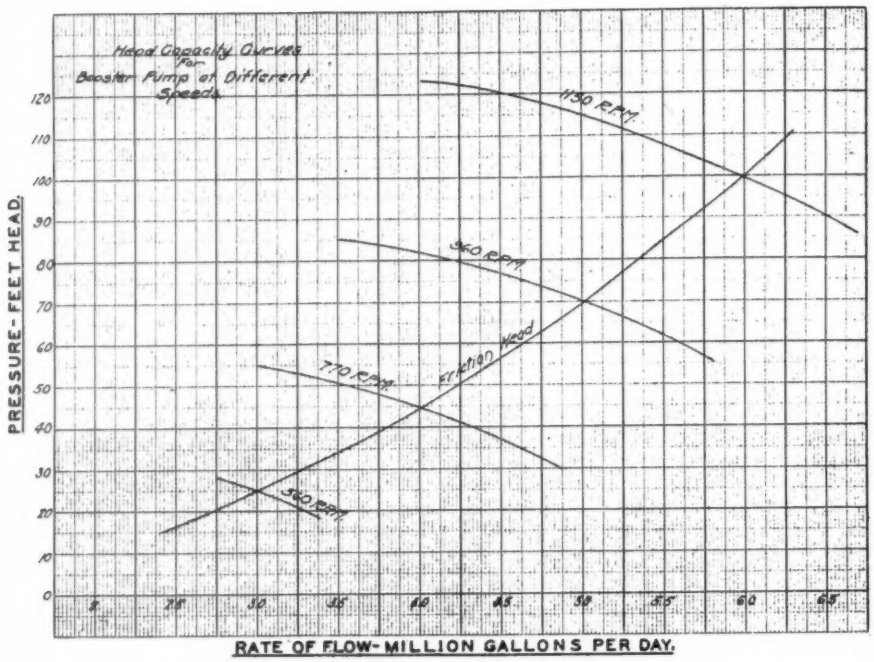


Fig. 2—Characteristics of Booster Pump at Different Speeds

Table No. I—Operating Data for Constant Speed Pumping Units

Rate of Pumping in M.G.D.	Pump Operating Numbers	Combined Efficiencies of Pumps Operating	Water Hp. Developed W-1	Total Losses of Unit in Hp. L-1
0	1	0	0	
.8	1	65	23.9	15.9
1.2	1	75	30.2	14.2
1.2	2	75	40.3	19.5
1.6	2	81	51.5	19.1
2.0	2	82	59.0	20.7
2.3	2	75	63.5	30.4
2.3	3	60	74.3	63.0
2.6	3	73	79.5	36.5
2.9	3	79	84.5	34.3
3.4	3	80	86.0	31.0
3.4	1-3	69	103.0	63.0
4.0	1-3	79.5	111.0	44.6
4.6	1-3	80.0	117.0	45.5
4.6	2-3	74.0	142.0	71.0
5.2	2-3	78.7	145.0	60.6
5.6	2-3	76.5	142.0	63.6
5.9	2-3	74.0	140.0	70.0
5.9	1-2-3	78.0	165.0	70.0
6.0	1-2-3	78.3	172.0	72.3

tion of the head capacity characteristics of the two small centrifugal pumps the pressure at the center of distribution may be maintained within reasonable limits without the expedient of the variable speed unit. These two units may be brought into operation or taken out of operation as may be desired by means of a pressure regulator type of control—pump No. 1 being cut out of operation when pump No. 2 is started. For this combination of pumps the rates of discharge at which pumps are started are shown in Fig. 3. The minimum pressure desired at the center of distribution determines the rate of discharge at which each pump is put into service. In this case a new pump of greater capacity is started when the pressure maintained at the center of distribution drops to 140 ft. head.

The variable speed unit will be put into operation when pump No. 3 is unable to keep the pressure above the minimum desired, and will operate at all higher discharge rates. Its speed can be varied by variation of the resistance in its secondary circuit using a motor-driven rheostat, the control being somewhat similar to that used for control of field rheostats on large generators to maintain a constant voltage.

Pilot wires can be used to connect the pump station to the center of distribution so that the entire control can be operated by that means. The loss of head through the metering device can also be used if desired as it is proportionate to the discharge, however, due to the variations in friction losses due to variations in the point of use in the distribution system, the method of using the pressure at the center of the distribution for control is preferred.

Calculation of Efficiency of Operation.—The efficiency for any discharge up to the rate at which the booster is cut into operation can be easily obtained from the ordinary data obtainable for both pumps and motors. When the booster is in service, the losses in the rheostat must be added to the losses in the motor. In order to make this study of efficiencies, an operating scheme must be set up for the different pumping units. Table I shows the pumps operating for various rates of discharge desired, with the efficiencies for the pump operating or the combined efficiency if two or more pumps are operating, the water horsepower developed and the total losses expressed in horsepower.

Table II shows the operating data for the variable speed unit. It gives the speed for different rates of discharge, the water horsepower, the power input and the total losses expressed in horsepower.

The total overall efficiency of the pumping installation is defined here as the ratio of the total water horsepower to the total power used by the motors including all resistance losses. The

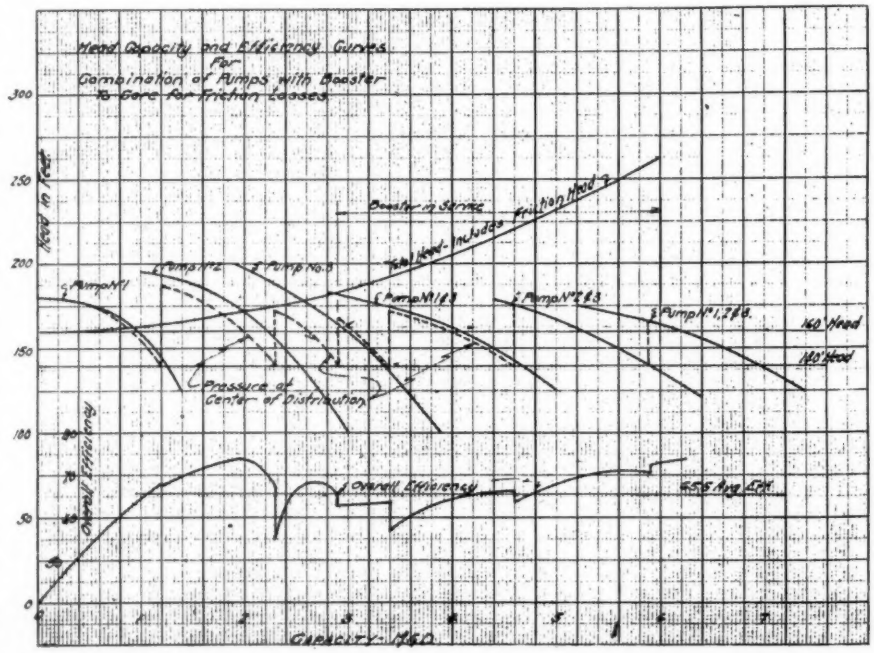


Fig. 3—Head Capacity and Efficiency Curves for Combination of Pumps with Booster

Table No. II—Operating Data for Variable Speed Units

Rate of Pumping in M.G.D.	Motor Speed R.P.M.	Water Hp. Developed W-2	Power Input Hp.	Total Losses of Unit in Hp. L-2
2.9	540	12.1	16.2	24.0
3.4	640	18.9	24.0	30.0
4.0	770	30.6	37.0	32.0
4.6	830	47.8	58.3	38.1
5.2	1,000	68.0	82.0	34.0
5.6	1,060	84.5	101.0	29.5
5.9	1 130	99.9	119.0	29.1
6.0	1,150	105.0	125.0	29.0

following Table III gives the total water horsepower which is the sum of columns designated as W-1 and W-2 in Tables I and II. The column marked total losses is the sum of the losses for the constant speed pump and the variable speed pump given in Tables I and II under columns designated as L-1 and L-2.

The water horsepower plus the losses gives the total power required for eacn rate of discharge and from these data the overall efficiency is calculated and is tabulated in the last column in Table III below.

Conclusions.—Possibly better economy could have been obtained at some points by making some slight changes in the pumps selected for this particular case. However, the results obtained from this study are such an improvement over the ordinary direct pressure centrifugal pumping installation that it deserves full consideration where there are limited funds available for improvements.

If it is necessary in some cases to operate centrifugal pumping stations on a direct pressure system with the resulting low economy usually obtained it certainly behooves engineers and waterworks operators to seek some method of improving the conditions. The efficiency indicated here is approximately 65 per cent overall while present operation of direct pressure motor-driven stations is approximately one-half this.

The automatic feature of operation is saving in labor, but above all else it insures that the right pump is operating to obtain the best economy. Where the control is manual, pumps will not be started and stopped at the correct time. Less disturbance to electric and water systems is caused by automatic starting and stopping because it is done in the proper manner and at the correct time.

Acknowledgment.—The above is an abstract of a paper presented at the 49th annual convention of the American Water Works Association.

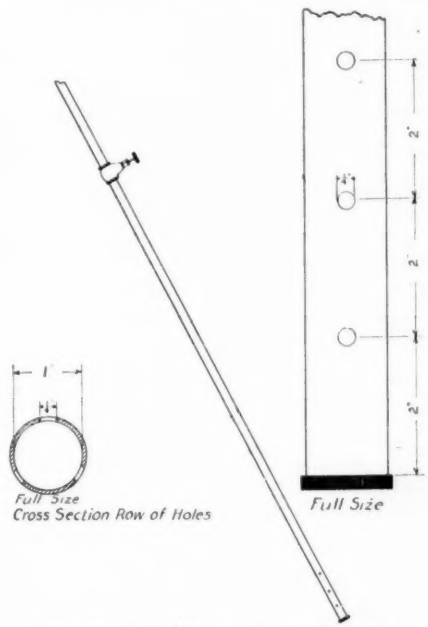
Table No. III—Overall Efficiency

1 Rate of Pumping in M.G.D.	2 Pump Operating Nos.	3 Total Water Horsepower $3=W_1+W_2$	4 Total Losses Horsepower $4=L_1+L_2$	5 Power Input Horsepower 5=Col. 3+Col. 4	6 Overall Efficiency in Per Cent 6=Col. 3/Col. 5
.8	1	23.9	15.9	39.8	60.2
1.2	1	30.2	14 2	44.4	68 1
1.2	2	40.3	19.5	59.8	67.5
1.6	2	51.5	19.1	70.6	71.6
2.0	2	59.0	20.7	79.7	74.0
2.3	2	63.5	30.4	93.9	67.5
2.3	3	74.3	63.0	137.3	54.5
2.6	3	79.5	36.5	116.0	68.5
2.9	3	84.5	34.3	118.8	65.6
2.9	3-B	96.6	58.3	154.9	62.4
3.4	3-B	104.9	61.0	165.9	63.3
3.4	1-3-B	121.9	93.0	214.9	56.8
4.0	1-3-B	141.6	76.6	218.2	64.6
4.6	1-3-B	164.8	83.6	248.4	66.2
4.6	2-3-B	189.8	109.1	298 9	63.8
5.2	2-3-B	213.0	94.6	307.6	69.2
5.6	2-3-B	226.5	93.1	319.6	71.0
5.9	2-3-B	239.9	99.1	339.0	70.8
5.9	1-2-3-B	264.9	99.1	364.0	72.5
6.4	1-2-3-B	277.0	101.3	378.3	73.2

Breaking Up Mud Holes in a Filter

BY A. L. GOSNELL
Filtration Plant Operator, Laurel, Md.

In a recent discussion a question was asked about using a hose nozzle to break up mud balls in a filter. This same question was asked several months ago at the North Carolina section, A. W. W. A. It was this question that caused me to make the implement that I wish to explain in this article. Instead of a hose nozzle, use a piece of 1 in. pipe about 7 ft. long. Screw a cap on lower end of pipe, and put a 1 in. valve about 1 ft. from upper end. Drill nine ¼ in. holes in this pipe just above the cap, beginning 2 in. above the cap. Space holes 2 in. apart and make three rows with three holes in a row, divided equidistant around the pipe. This completes the nozzle end. It may be well to make the nozzle out of a short piece of pipe, so that in case you wanted to make a change, you could take it out and replace it with another. Attach a 1¼ or 1½ in. hose from this pipe to the high pressure water line. When ready to wash a filter, place a piece of 2 in. plank across the wash troughs to stand on. Start up wash pump, open up high pressure line through 1½ in. hose to nozzle, stand on the plank and push nozzle down through mud pockets while wash pump is running. The nozzle will break up the mud balls and the wash pump will bring them to the surface. It may be necessary to scrape the filter after this is done. Care must be taken to cap the lower or nozzle end of this pipe tight, as otherwise you might disturb the gravel bed. All streams from this nozzle must come out through the sides and not through the bottom. If conditions are such that the wash pump could not be run at full capacity for 5 or 10 minutes, or if there is a considerable amount of mud balls to be removed, open the wash valve about one-quarter way, and work on mud pockets 5 or 10 minutes. Cut out nozzle and open wash valve wide. The wash pump should run at its maximum capacity 3 or 4 minutes after nozzle is cut out. We have been using this home made implement about three weeks and find that it does good work.



Home Made Implement for Breaking Up Mud Balls

Water Company Employes to Wear Uniforms

All employes of the Hackensack Water Co., Weehawken, N. J., whose duties require them to enter homes of consumers will hereafter be uniformed, it is announced by the president of the company, Nicholas S. Hill, Jr.

Inspectors, meter readers, and collectors will be attired in dark gray whipcord with the insignia "H. W. C.," in red, on the right breast, and will wear caps bearing the letters "H. W. C.," also in red.

The purpose of the uniforms, Mr. Hill explained, is to enable customers to identify Water Company employes, and to guard against unwarranted intrusion of homes by imposters who in the past have not infrequently posed as representatives of the company.

In deciding to adopt uniforms, the company acted upon the unanimous recommendation of its departmental heads.

Aggregates for Sewage Disposal Plants

Characteristics and Behavior in Practice of Three Materials

By HERBERT F. KRIEGE

In Charge of Tests, France Stone Co. Laboratories, Toledo, O.

WITH the increase in population about many centers the welfare of the growing communities depends upon the proper control of sanitation and hence to a great extent on effective sewage disposal. The types of disposal systems most widely used in this country are those employing contact and trickling filter beds. In both of these types, mineral aggregates are used as media for the beds. It is the purpose of this paper to discuss the characteristics and behavior of the various materials utilized in this connection in terms of conditions imposed upon them by usage.

The earlier types of sewage disposal systems, other than mere dilution in large streams or bodies of water, consisted of areas of sand or other small material over which the sewage was allowed to flow intermittently, thus exposing it to greater oxidizing and bacterial activities than it received upon slight dilution. As the quantity of sewage increased, the contact process was improved so as to consist of a well-defined area provided with good under-drainage and containing a mass of grosser mineral particles such as broken stone, slag, gravel, cinders, etc. The system as now used permits the slow filling of this contact bed with sewage which has previously had its heavier solids settled out, the sewage remaining in contact with the medium of the bed for a period of time, after which it is allowed to drain away through the under-drainage system. During this time of contact, a certain degree of stability has been reached through the partial oxidation of the organic substances contained in the sewage by the bacterial colonies lodged on the surfaces of the medium.

The contact method, though by no means discontinued, is giving way to the trickle filter bed system. This consists of an enclosed bed of aggregate, usually stone or slag, over which the sewage, after settling or treatment in the Imhoff tanks, etc., is sprinkled by means of sprays or traveling distributors. The sewage thereby receives some aëration before it comes in contact with the bacterial life on the medium. At all times in a properly functioning trickle filter bed, the large voidage provides for sufficient aëration to keep the bacterial colonies and sewage supplied with the oxygen demanded in the biochemical processes. During the time interval required by the sewage to trickle down the aggregate mass to the under-drain, a sufficient stability has been effected in the sewage to permit its passage directly into even small streams without creating a nuisance. The capacity of the trickle filter system is quite large, and hence this serves in congested areas as a satisfactory and efficient sewage disposal method.

Trickling Filter Systems—The distribution of the trickle filter systems through the United States is rather wide. According to the 1927 Progress Report to the American Society of Civil Engineers the Filtering Materials Committee of the Sanitary Engineering Division found that in 19 states east of the Mississippi River a total of 142 plants were in use serving a population of 2,800,000. West of the Mississippi River, nine states reported a total of 246 plants serving a population of 1,240,000, making a combined total of 388 plants serving 4,040,000 people in the 28 states reporting prior to April, 1927. Since that time a survey by the author has added 97 plants, serving an additional population of 754,950, making a total reported up to April, 1929, of 485 plants in 34 states. The distribution of these plants is stated more specifically in Table I.

Table I.—Installations of Sewage Filter Plants Reported with Approximated Population Data

States East of the Mississippi River

State	All Plants Reported Number	Approximate Population
Alabama*	1	80,000
Connecticut*	1	6,000
Delaware	2	4,100
Georgia*	4	385,000
Illinois	34	453,200
Indiana*	5	30,000
Kentucky*	2	53,000
Maryland	10	615,600
Massachusetts*	4	304,000
Michigan	9	96,400
Mississippi	1	11,000
New Jersey*	18	103,600
New York	25	214,400
North Carolina	12	60,350
Ohio	28	590,000
Pennsylvania*	14	76,000
Rhode Island	2	13,400
Tennessee	7	27,100
Virginia*	6	12,000
Washington	1	20,000
West Virginia	2	6,400
Wisconsin	13	70,500
Total east of Mississippi River	201	3,232,050

States West of the Mississippi River

State	All Plants Reported Number	Approximate Population
Arizona*	2	13,700
California*	14	49,700
Colorado*	4	20,500
Iowa*	38	94,300
Kansas	19	82,600
Minnesota	6	45,300
Missouri	22	131,600
North Dakota	2	24,500
Oklahoma	45	318,000
Oregon	1	10,000
South Dakota*	9	54,700
Texas*	122	718,000
Total west of Mississippi River	284	1,562,900
Grand Total	485	4,794,950

*Data taken from the April, 1927, Progress Report of the Committee on Filtering Materials, Sanitary Engineering Division of the American Society of Civil Engineers.

Types of Aggregates—The aggregates which have come into most general use in both contact and trickle filter beds are broken stone, including both sedimentary and igneous rocks, blast-furnace slag and occasionally gravel, cinders, broken tile, broken retorts, etc. This variety in types of aggregate has been brought about by the desire to find some medium which would give a large effective surface for lodgment of bacterial life and yet would be an economically possible material. Experience has shown that certain of these aggregates are distinctly superior to others as to durability and general effectiveness.

In considering the requirements which the medium in a trickle or contact bed must meet, the conditions imposed by such usage need discussion. In practice the medium is intermittently wetted with the sewage and allowed to drain. This facilitates any disintegration or attack which hydration and oxidation under moist conditions might bring to pass. The action becomes particularly severe when during the winter months the aggregate is repeatedly frozen while wet and thawed by subsequent applications of the warmer sewage. In the trickle bed a dosing period of three to six minutes followed by a rest period of ten or fifteen minutes is not uncommon. This means that in twenty-four hours the filter bed medium may be alternately frozen and thawed nearly one hundred times, provided the temperature of the air is well below freezing. This becomes perhaps the most severe test which mineral aggregate is called upon to withstand in industrial practice. The properties of mineral aggregates which will enable them to withstand these conditions of intensive weathering will be considered separately.

The rapid growth in all lines of highway and building construction has required a more rigid classification of materials suitable for the work. The characteristics most commonly specified

and tested for in mineral aggregates are hardness, toughness, abrasion, absorption, weight per cubic foot and soundness. It is quite natural, then, that the group of engineers interested in sewage disposal practice should call upon these same specifications and test procedures to determine the suitability of media in sewage treatment. Some questions may be raised, however, as to the advisability of this plan since it may lead to a false conception of what constitutes the best material for this specific purpose. It is perhaps advisable that as much thought be given color, uniformity, crystallinity, fracture, cleavage, and the screen analysis with the percentage of voids of aggregates in the selection of the material. Roughness has been discussed though without any definite recommendations being made since no easy measure for the degree of roughness has been reported.

Hardness.—The hardness as commonly determined for aggregates is the resistance to wear or abrasion under standard conditions as prescribed in the procedure for the Dorry hardness test. The occasions on which either contact or trickle filter media are called upon in practice to show resistance to wear are few, about the only movement which the material passes through being that involved in the placing of the material in the bed. Hardness is no criterion of the durability of aggregates, particularly in the sedimentary stones which find quite general use in sewage disposal work. One of the hardest of the common minerals associated with the limestone deposits of this country is the practically pure silica mineral known as chert. This has a hardness approximating that of quartz, yet one form of it is a readily disintegrating material upon exposure to weather or sewage treatment. Likewise the hardest limestones are very often the ones that show the greatest tendency toward disintegration when exposed. This applies equally well to gravels composed largely of limestone particles. In the case of blast-furnace slag, which may be either dense, medium dense or honeycombed, the dense variety is naturally the hardest and yet this is more apt to show splitting either in actual or in experimental freezing and thawing or in the sodium sulfate test than is the medium dense or the honeycombed slag.

Toughness.—Since toughness is taken as the measure of the resistance of the material to impact, the same conditions referred to for hardness may be applied in this case. Practically the only impact which the material receives is during the placing. Aggregate of but moderate toughness can easily withstand that amount of impact. Likewise aggregates of great toughness often do not show any greater resistance to the disintegrating action of wetting and drying, freezing and thawing, than do those of lower resistance to impact. It does not seem advisable therefore to discriminate against an aggregate of lower toughness value for this reason only.

Abrasion.—The resistance to wear of one piece of aggregate against others and against the walls of the containing vessel is sought for in the standard abrasion test. This characteristic is somewhat allied to hardness and toughness and what applies to them applies also to abrasion. Argillaceous limestone and some chert may be mentioned in this connection since their abrasion losses are very low, yet their suitability for filter bed use may be very seriously questioned.

Absorption or Porosity.—Density in the mineral aggregates entering contact and trickle filter beds has been sought for quite generally, on the supposition that material which absorbs the least water or has the lowest pore space will be the one longest surviving the disintegrating action of freezing while wet. Woolf[1] has recently shown that when all types of naturally occurring aggregates are considered, igneous and sedimentary stones being included, the resistance to disintegration by five sodium sulfate immersions is somewhat in relation to the density of the stone. Unpublished data secured in the laboratory of the France Stone Co. show that this does not hold true when applied to limestones and dolomites and their associated minerals, particularly when the sodium sulfate test is carried to twenty cycles. The relation between the soundness as determined by these tests and the absorption on several hundred samples of such materials is highly irregular.

Weight per Cubic Foot.—From an economic standpoint at least, the weight per cubic foot has some bearing on the use of a certain medium. The purpose of the medium is simply to provide a sufficiently large surface on which the bacterial life may lodge to effectively alter the sewage in contact with it. Hence, the smaller weight of material used to provide this surface, the lower will be the cost, other things being equal. In this way one aggregate of lower density or higher porosity, even though it shows a higher abrasion loss, lower toughness and lower hardness, may be the proper one to use. Since a difference in weight of 500 lb. per cubic yard is not unusual between moderately porous limestones and dense trap rocks or gravel consisting largely of igneous material, it can easily be recognized that the unit weight is a definite factor in the economics involved. On comparing a honeycombed slag with the dense stone, the difference will be even greater.

Table II—Relation of Type of Medium to Trickle Bed Clogging Tendency

Material	Number of Plants Reporting	Average Total Years of Service	Percentage Showing Clogging
Limestone	51	8	48
Granite, trap	29	7	23
Blast-furnace slag	11	8	18
Gravel	8	6	50

Color.—While it may appear that color has little if any bearing on the characterization of the material for its use in sewage disposal practice, certain observations which may be made by visual inspection will prove helpful in the selection of the right material. Color is often an index to the chemical composition or the presence of certain minor constituents which may have a bearing on the general properties of the material. Usually the yellows, reds and browns indicate that the material has already been subjected to oxidizing conditions, while the blues, greys and blacks denote the presence of unoxidized substances such as carbon or iron compounds. Material already in the oxidized state may be expected to undergo less change upon further exposure than one in which this oxidation has not yet occurred. The presence of small amounts of silt, clay, beidellite and organic films can be detected more easily by color or luster differences than by any other simple means. In the case of limestones in the central states, some strata having a dull lusterless ash-gray color on fresh fracture may be regarded with suspicion, regardless of their other physical and chemical properties, since usually they show very little resistance to weathering action.

Uniformity.—The lack of uniformity in composition, kind of material, structure, and texture may be taken as an evidence of lessened resistance to the action of weathering. In the freezing-and-thawing experiments or other accelerated weathering tests the first evidences of the disintegrating tendencies seem to occur at points of non-uniformity in the material. Laminations, sutures, imbedded accessory crystals or masses, and inclusions, be they of microscopic or macroscopic size, appear to be the weakest portions of the defense against disintegration of the material. Blast-furnace slag which has every reason to be uniform in composition is a good example of how this uniformity beneficially affects resistance to freezing and weathering in general. These remarks should not be construed to mean that any material which is uniform is necessarily stable and resistant to disintegrating forces. Lack of uniformity however must be given due consideration when characterizing a material for use in exposed conditions. Reference should be made again to some chert whose tendency to disintegrate is so pronounced while its most closely allied mineral, namely, flint, is a common synonym for durability. In a recently published article by the author[2] the instability of disintegrating chert is attributed more to lack of uniformity in mineral structure and to enclosed

[1] D. O. Woolf, Jr., *Public Roads*, Vol. 8, December, 1927, p. 225.

[2] H. F. Kriege, "The Stability of Chert," Rock Products, Vol. XXXII, No. 9, April 27, 1929, p. 50.

crystallin foreign masses than to any other observed property.

Crystallinity.—Whether a material is holocrystallin, grossly or finely crystallin, crypto-crystallin or amorphous does not seem to have any great bearing upon its behavior in trickle or contact bed use. However, when within a single piece of aggregate the crystallinity changes definitely, such as a zone of gross crystals within a finely crystallin or amorphous mass, or an amorphous clayey seam within a well crystallized mass, such structures encourage disintegration at that point. Since in the preparation of crushed mineral aggregates for the market the weakness of such structures are usually found by the fracture stresses during the crushing operation, not many of these weak planes persist in the finished pieces.

Fracture and Cleavage.—The fracture and cleavage habits of the commercially prepared products have some bearing on their fitness as filter media. The tendency toward slabby pieces is undesirable since this tends to produce a low voidage in the resultant bed due to overlapping of these slabby pieces in layers like shingles of a roof. Those fracture habits which leave the prepared aggregate with angular shapes and irregular surfaces are most desirable. In this property, slag, trap rock, and granite are most commonly in the desired class. Sedimentary stones free from shaley or slatey material likewise fall into this category.

Roughness.—Since roughness largely determines the amount of surface which a piece of aggregate offers, this property should be taken into account in the selection of a medium for purposes utilizing its surfaces. Experiments conducted at Philadelphia[1] to show the relative efficiencies of aggregates varying widely in their shape and roughness brought out the fact that the rougher the material the more efficient it was in the oxidation and stabilization of the sewage influent. The extremes of roughness in materials available commercially are well rounded gravel on the one hand and honeycombed slag on the other. The opinion has been expressed by some sanitary engineers that slag offers too great a roughness, that this roughness tends to hold the bacterial colonies and collected solids too long so that clogging of the bed is produced. The Progress Report of the Committee on Filtering Materials[2] contains some data pertaining to the effect of type of medium on the clogging tendencies. These have been rearranged in tabular form shown in Table II.

It appears, therefore, from actual experience gained with trickle beds operated in widely separated districts that clogging is not so common with highly irregular and rough surfaced material like slag as with the smooth, rounded gravel.

In February, 1929, the author saw the larger of these slag beds reported in the table above as having clogged. At the time of inspection (during a rest period) it was entirely clean, practically the only evidence that it was not freshly placed slag being a general iron stain covering the surfaces of the slag pieces in the zone of the sprays. This stain was apparently due to the iron compounds contained in the influent. A rest period of several months had completely relieved this bed of its clogging material even though it had been heavily overloaded for twelve years with an industrial and domestic sewage which was difficult to treat. Mr. C. C. Hommon,[3] in charge of the Canton sewage disposal plant, after examining all the known trickle beds using blast-furnace slag in the filtering medium, reported 29 on which no clogging had occurred, while 12 showed clogging or clogging tendencies. However, the tendency to clog in the latter cases could be explained in every instance (1) by poor sizing of the material placed in the bed; (2) by excessive loading without rest periods, or (3) by the poor condition of the influent. On the other hand, perhaps the largest gravel bed now in use was observed by the author during February, 1929, and found to be in a very dirty condition, indicating that this may occur even on a bed composed of smooth rounded pieces. Clogging of trickle beds is therefore due to some factor other than the roughness of the surface of the medium.

Little has been definitely learned about the relative roughness of different filtering media. In order to arrive at some fair understanding of this property in limestones known to be different in their fracture and cleavage habits, the following tests were conducted in the France Stone Co. laboratories. It had been previously shown that the fracture habits of limestone persist into the smaller sizes when the stone is crushed. In this way it is possible to study the roughness of any convenient size of material, say of No. 4 to No. 6 sieve size, and use that as a standard for either the larger or the smaller fragments.

The procedure consisted of determining the amount of material dissolved in dilute hydrochloric acid under controlled conditions of temperature, acidity, agitation and time, from a known area of polished surface of the limestone sample. This gave the specific solubility rate for that kind of material per unit surface. This same weight of material of No. 4 to No. 6 size was run under identical conditions. Since solution takes place only at the surface of the dissolving substances, the different amounts dissolved from the polished and the naturally rough pieces were in relation to the differences of the surfaces exposed or in other words, to the roughness. By comparing the amount of material dissolved from a given weight of the stone particles with the amount that would have dissolved had these particles been true spheres, a numerical ratio of roughness (including both shape and surface irregularities) was obtained. Some of the values found in this investigation are given in Table III, to indicate how widely the degree of roughness may vary even within the same class of material, in this case dolomitic limestone.

Table III—Relative Roughness Value of Some Dolomitic Limestones
(Based on a spherical surface as unity)

	Description	Roughness Value
Limestone A	Almost cubical shape with smooth surfaces	1.39
Limestone B	Fairly cubical shape with smooth surfaces	1.60
Limestone C	Fairly cubical shape with rougher surfaces	1.84
Limestone D	Fairly cubical shape with rougher surfaces	1.87
Limestone E	Irregular fracture, angular shape and fairly smooth surfaces	2.01
Limestone F	Irregular fracture, angular shape and irregular surfaces	3.01
Limestone G	Irregular fracture, angular shape and irregular surfaces	3.10

The method is not applicable to slags and other silicates.

Soundness.—Since the characteristic which most largely determines the usefulness of an aggregate for filter bed use is its ability to resist breaking down under the actions and forces imposed by service, several laboratory methods for predicting the behavior of materials in use have been developed. The more successful ones consist of (1) actual freezing and thawing at relatively short intervals and (2) a drying and soaking process in solutions such as sodium sulphate and sodium chloride in which the destructive effect of the crystal growth of the solution contained in the pores of immersed material is used as a measure of its resistance to actual freezing conditions. A more satisfactory method of testing, where time permits, is to expose the material in question upon the surface of some trickle bed in operation and to observe its behavior through a period sufficiently long to warrant conclusions being drawn. This method is being used by several sanitary engineers and aggregate producers.

From a laboratory standpoint, the sodium sulphate test for soundness is perhaps the most acceptable since it involves but little apparatus, labor, or space and results can be obtained within several weeks. An attempt has recently been made by the Committee on Filtering Materials of the A. S. C. E. to standardize the procedure for this test sufficiently to permit the same type of behavior to be found with a material sent to different laboratories for testing. While the results of this work have not

[1]Report Sewage Testing Station, page 120; also William Metcalf and H. P. Eddy, "American Sewerage Practice," Vol. 3, p. 555 (1916).
[2]Loc. cit.
[3]Unpublished report to the National Slag Assn.

yet been made public, it is believed that such an effort is well worth while and that it will show that no consequential variations result if the several laboratories observe the outlined procedure with fair accuracy. The procedure as followed in the France Stone Co. laboratories consists of immersing the samples, which have been dried for four hours at 105° C., in a solution of sodium sulphate which has previously been saturated at 30 to 35° C. and allowed to cool to room temperature. One cycle consists of 20 hours' immersion and 4 hours' drying, the specimens being examined immediately after removal from solution for any signs of disintegration, checking, flaking, cracking, etc. The number of cycles is usually 20, this number having been arbitrarily set as indicating a sufficient degree of resistance to expect long life in actual practice.

The materials which show distress early in the sodium sulphate test are (1) shales, (2) slatey material, (3) stone with carbon seams, (4) limestones with high non-carbonate content and (5) limestones containing chert of the kind which tends to disintegrate. Usually the destruction of these occurs before ten cycles are run, often before the fifth cycle. Blast-furnace slag, granite, trap rock and other igneous materials are noteworthy in their ability to resist the sodium sulphate test. Likewise these same materials show little disintegration in use in the filter beds. Limestones with their wider range in composition, structure and association show all ranges of resistance to this test and to actual weathering.

Types of Disintegration.—There is considerable confusion as to what types of disintegration are most serious to the effective service of the filtering medium. Some fear the crumbling type of disintegration, others the splitting into slabby pieces. Obviously that type of disintegration which provides material either (1) large enough to cause void reduction within the mass of the bed or (2) small enough to be retained by the organic matter near the surface of the bed would tend to lower the efficiency of the filtering medium. In order to describe more fully the types of disintegration which may occur in stone samples, the following key is given, which has been used in recording all the varieties of distress noted in the author's soundness tests. The amounts of material broken off during all of these forms of failing are indicated in grams.

A.....Horizontal split into 2 pieces.
A3, 4.....Horizontal split into more pieces.
B.....Vertical split into 2 pieces.
B3, 4.....Vertical split into more pieces.
H.....Horizontal chips from 1 piece.
H2, 3.....Horizontal chips from 2 or 3 pieces.
V.....Vertical chips from 1 piece.
V2, 3.....Vertical chips from 2 or 3 pieces.
Ban.....Banding failure.
C.....Imminent checking and splitting.
Ch.....Failure around cherty inclusions and limestone contact.
Chv.....Failure across cherty inclusions and limestone contact.
Cr.....Failure of crystals at contact.
D.....Complete disintegration by crumbling, etc.
D1, 2.....Number of pieces showing complete disintegration by crumbling, etc.
F.....Flaking—scaling on any side, horizontal or vertical.
I.....Infilling crumbling.
L.....Laminations failing.
R.....Broken pieces retained in the series to observe further breaking action.
S.....Surface solution effect.
Sc.....Scaling at surface.
Sh.....Shale failing.
Su.....Sutures failing.
OK.....Passed through individual test successfully.

Considerable work has been done by Orton,[1] Staley,[2] Withey,[3] Schlick[4] and other investigators with mineral aggregates and other non-metallic structural materials to find the relationship between the effects of freezing and thawing, either in the natural or the accelerated state, and the laboratory results of sodium sulphate, sodium chloride, magnesium sulphate, alkali and boiling and drying tests. No fixed relationship has been observed, however, the values of one sulphate cycle ranging from less than one to nearly one hundred freezing cycles with different types of materials or conditions of testing. Perhaps the most logical method is that suggested by G. B. Gascoigne,[5] in which the behavior of an untried material is predicted from the comparison of its

[1]Edward Orton, Jr., "A Study of the Proposed A. S. T. M. Tentative Specifications for Building Brick and a Correlation of Their Requirements with Sodium-Sulfate Treatment and Actual Freezing," Proceedings, Am. Soc. Testing Mats., Vol. XIX, Part I, p. 268 (1919).
[2]H. F. Staley, Transactions, Am. Ceramic Soc., Vol. 18, p. 642 (1916).
[3]M. O. Withey, Proceedings, Fourth Annual Meeting Highway Research Board (1925).
[4]W. J. Schlick, Bulletin 89, Engineering Experiment Station, Iowa State College (1928).
[5]G. B. Gascoigne, Unpublished report on trickler filter media.

Table IV—Field Observations and Laboratory Tests of Slag Used as Trickle Bed Media

Plant Location	Operated Since	Disintegration of Material	Weight per Cubic Foot, Loose, lb.	Absorption, per cent	Apparent Specific Gravity	Voids, per cent	Abrasion, per cent	Soundness Behavior OK after 20 Cycles unless otherwise stated	Chemical Composition						
									Silica, per cent	Alumina, per cent	Ferric Oxide, per cent	Manganous Oxide, per cent	Calcium Oxide, per cent	Magnesium Oxide, per cent	Sulfur, per cent
Akron, Ohio	1916	Little evidence of true disintegration	60	2.6	1.98	44.0	16.1	OK	33.10	12.22	1.08	0.88	40.23	7.25	0.64
Amherst, Ohio	1928	None	68	3.8	2.17	49.8	7.0	OK	36.38	11.24	0.70	1.25	43.04	5.51	1.16
Bay Head, N. J.	1916	None	55	5.4	1.87	45.1	16.8	OK	37.04	9.38	0.76	0.79	38.75	12.36	0.54
Battlewood, N. J.	1922	None	58	2.7	2.04	46.5	17.7	OK	35.60	12.70	0.50	0.94	37.58	10.97	0.83
Bolivar, N. Y.	1928	None	61	4.2	2.07	45.0	14.8	OK	36.86	11.70	1.88	1.06	42.32	4.63	1.20
Camp McClelland, Ala.	1918-1919	Little disintegration	63	3.2	2.04	42.6	10.8	OK	38.16	10.93	2.41	0.53	36.93	6.31	0.62
Canton, Ohio	1925	None	58	3.8	1.96	44.4	17.8	OK	34.28	13.30	0.70	1.07	40.05	6.60	1.31
Colwick, N. J.	1926	None	59	6.2	1.88	42.0	16.3	OK	37.56	11.49	1.01	0.86	30.87	14.77	1.06
Dixmont, Pa.	1910	None	63	2.0	2.12	44.0	8.8	OK	36.38	12.91	1.01	0.76	42.71	3.74	0.97
East Aurora, N. Y.	1923	Small amount splitting	62	3.8	1.96	41.9	11.8	OK	36.50	16.78	0.50	0.85	37.71	3.23	1.13
Edgewater Mines, Ala.	1917	No true disintegration	51	5.1	1.85	47.9	17.9	OK	36.64	11.61	0.51	0.48	38.98	8.48	0.33
Edgewater Mines, Ala.	1925	None	51	5.1	1.85	47.9	17.9	OK	36.64	11.61	0.51	0.48	38.98	8.48	0.33
Erie County, Pa.	1924	None	66	1.5	2.29	47.5	13.9	OK	36.72	9.72	0.50	1.14	43.61	8.54	0.90
Fairfield, Ala.	1914	No late disintegration	..	2.6	2.29	..	11.0	[a]	38.60	10.20	1.34	0.76	41.48	5.88	0.68
Glassboro, N. Y.	1926	None	57	4.9	1.89	44.0	15.2	OK	36.06	12.19	0.77	1.64	34.20	12.44	1.14
Haddonfield, N. J.	1920	None	56	6.4	1.93	46.0	18.8	OK	36.00	13.14	0.76	0.78	34.11	12.34	0.68
Hammonton, N. J.	1914	None	63	7.8	2.04	43.4	21.3	OK	41.60	12.79	1.01	0.85	29.80	11.63	0.65
Ishkooda Mines, Ala.	1921	None	62	2.0	2.16	47.3	12.5	OK	38.30	11.21	0.51	0.73	40.77	6.45	0.52
Leetonia, Ohio	1925	Little disintegration at surface	59	3.9	1.85	41.9	19.6	OK	32.62	14.44	0.76	0.62	43.46	2.67	0.94
Maple Shade, N. J.	1927	Very little disintegration	58	5.8	1.88	42.8	16.8	OK	36.28	12.43	0.63	1.37	33.88	13.85	1.52
Media, Pa.	1924	None	57	4.0	1.87	43.4	17.8	OK	38.24	12.10	0.63	1.24	36.30	10.09	1.45
Johnson City, Tenn.	1924	None	75	2.7	2.31	40.3	14.2	OK	39.18	5.58	0.64	0.60	34.78	16.14	0.49
Muse, Pa.	1925	None	64	4.0	2.29	48.9	14.7	OK	34.34	13.73	0.57	0.83	42.13	3.35	1.40
Oaklyn, N. J.	1915	None	57	5.7	1.93	44.3	17.2	OK	38.16	11.72	0.70	0.72	34.86	10.82	0.49
Pitman, N. J., Number 1	1917	No true disintegration	61	3.7	1.98	43.3	15.3	OK	36.42	12.75	0.89	1.02	35.23	11.40	0.82
Quakertown, Pa.	1927	None	56	5.7	1.99	47.6	16.8	OK	35.01	12.92	0.38	1.09	35.90	12.71	1.11
Birmingham, Ala.	1926	None	65	2.5	2.14	43.0	7.6	OK	39.04	10.40	0.70	0.58	39.69	6.08	1.01
South Coatesville, Pa.	1916	None	64	4.1	2.00	40.7	24.7	OK	33.68	12.10	2.52	0.39	42.61	2.16	0.91
Buffington, Ind.	1926	None	73	2.2	2.40	44.5	8.4	OK	39.12	11.14	0.72	1.07	42.84	3.74	1.24
Universal, Pa.	1927	None	67	2.6	2.35	46.1	11.7	OK	34.92	13.23	0.69	0.59	42.49	5.10	0.94
Birmingham, Ala., Jefferson Co.	1919	None	..	3.8	2.00	....	9.0	OK	35.34	11.41	1.41	0.56	41.84	7.99	0.49
Westmont, N. J.	1921	None	58	5.3	1.84	41.6	16.4	OK	35.70	13.41	0.33	1.08	38.79	7.35	0.80
Woodbury Heights, N. J.	1922	Marked evidence of disintegration	55	4.7	1.91	46.3	18.3	[b]	34.04	13.01	0.63	0.62	40.78	10.01	0.72
HIGH			75	7.8	2.40	.....	.....	.....	41.60	14.40	2.52	1.64	43.61	16.14	1.52
LOW			51	2.0	1.84	.....	.....	.....	32.60	5.58	0.33	0.39	30.87	2.67	0.33

[a] 1 small chip at eighteenth cycle.
[b] 1 piece in two at twelfth immersion, 1 piece in two at fourteenth immersion, 1 piece 10 in parts at seventeenth immersion and 1 piece in 7 parts at eighteenth immersion. Contained small piece of coke impregnated with iron.

accelerated weathering resistance with that of a material known to be satisfactory both in test and service. Nevertheless it is becoming more evident as our experience with filter media increases that a material which will withstand 20 cycles of the sodium sulphate test as is most widely followed today,[1] can be expected to stand up well for several decades under the severe conditions imposed by actual service in trickle beds.

The factors directly affecting soundness of natural mineral aggregates of sedimentary origin are lack of chemical or physical uniformity within the specimen, more specifically existence of certain associated minerals such as shale, pyrite and some cherts, and the presence of considerable amounts of clayey material, beidellite, and similar hydrous alumino-silicates. The usually considered physical properties of hardness, toughness, abrasion, etc., play but minor parts in determining the life of filter material, as was pointed out in the discussion previous. The disintegration of granites and other igneous materials is so slow that the development of their factors of degradation is unnecessary in this connection.

Sometimes one finds a tendency to specify the chemical composition or some physical property for blast-furnace slag if it is to be considered for sewage disposal bed purposes. Such conditions as low lime, low sulfur, or low iron content are called for, with some thought being given to the density of the material. Slag, by the very reason of its existence, is made to conform to a definite chemical composition within narrow limits. It does not therefore seem the part of wisdom to arbitrarily set standards for slag if its use in a special field like sewage disposal is being considered. Rather it should be taken as it is if tests and use have demonstrated its suitability for that service. In Table IV are found data secured by Fred Hubbard of the Standard Slag Co., Youngstown, Ohio, on slags that were collected by C. C. Hommon from trickle and contact beds in service. It should be observed how little variation there is in these slag samples in both composition and in physical properties, and how uniformly well they have withstood the conditions of actual service and the subsequent 20 sodium sulfate cycles. These figures amply support the statement that the slight variations found in the chemical and physical properties of commercially prepared slag are of no significance to the durability of the material and its quality for sewage disposal beds.

The sole function of the medium in a trickle filter bed is to provide a large amount of well aerated surface. To maintain proper circulation of air within the bed, the medium should have a high percentage of large voids. Hence, if a material has a large specific surface, its excellence for this use will depend upon the factors controlling its voids. These are sizing, cleanliness and durability. In this day when the washing of commercial aggregates is so common, it should not be difficult to secure material of the desired cleanliness. Likewise proper sizing should be entirely within the control of the engineer in charge of the job and the producer of aggregates. Judging from beds now in operation, sufficient attention has not been paid to this matter of sizing. The quantity of fine material below that specified, not infrequently runs to 15 to 20 per cent of the total. This very definitely reduces the voidage of the bed and hence the air capacity and promotes clogging. According to statements of state health officers of several states in the Great Lakes region, improper sizing has contributed more often to the poor behavior of beds in these states than has disintegration of the material after placement.

Size of Aggregate.—A tendency to raise the minimum size of material is evident. Taking the sizes specified for some 50 plants into consideration, the average size of aggregate for the upper part of the bed is found to have changed with time in the following manner: previous to 1910, 1.1 to 2.8 in.; 1910 to 1915, 1.2 to 2.5 in.; 1915 to 1920, 1.7 to 3.2 in.; since 1920, 1.8 to 3.3 in. It is logical to expect a continued increase in the smaller dimension since this will provide for larger voids and less opportunity for imperfect oxidation or for clogging.

Another evil attending poor sizing is the tendency for the fine material to concentrate in portions of the bed during placement unless special care is taken to prevent it. Such areas invite trouble such as pooling and clogging since they offer greater resistance to the downward movement of sewage and the solids carried thereby. If the material has the property of cementation, this will be most apt to occur in such areas of concentrated fine particles. It is doubtful if cementation ever results from the accumulation of fine material broken down from the grosser pieces by disintegration.

Occasionally a trickle bed is reported to be giving unsatisfactory service. Usually the filtering medium is blamed for this condition. However it is well to ask concerning the operating practices of the plant. There are several well-known cases of the unsatisfactory performance of sewage plants in which the trouble was not due to the aggregates. Beds of granite have clogged, pooled and flooded until cleaning was necessary, yet no characteristic of the stone contributed to this trouble. The only explanation lies in the improper operation of such beds. Overloading is the most frequent operation abuse. This factor probably accounts for more trouble than any other.

Poor screening and insufficient settling of the sewage permit excessive quantities of solid matter to pass upon the beds. The accumulation of this foreign material contributes definitely to the clogging of the filtering medium. Surface drainage carrying run-off sediment to the bed constitutes another source of trouble. Unless proper provision is made against it the filter areas may become littered with leaves and similar debris. Each of these operating factors may impair or destroy the efficiency of a trickle or contact bed otherwise in good condition.

Suggestions for Producers.—As practical measures for producers of filter bed media, the following suggestions are offered:

1. Establish the durability of the material by laboratory tests (preferably sodium sulfate) and if possible by observing its behavior on the surface of a bed in operation through one winter. Field observation indicates that the disintegration of aggregate takes place almost entirely at the surface of the bed and to the greatest extent during the first year or two.
2. The inspection and testing of the stone quarry, slag bank, or gravel pit is not of as great importance as the testing of the prepared aggregate of the size desired for that use.
3. Cleanliness and close adherence to the size specified are of the utmost importance. Such attention and effort will involve a slight additional cost, but it greatly improves the quality of the material and makes it distinctly worth more to the consumer.

Conclusions.—The conditions imposed by sewage disposal practice in which mineral aggregates are used in trickle filters or contact beds are very severe. However, aggregates of sufficient durability to be used in this practice are commercially available in most sections of the country. The function of the medium is to provide a large well aerated surface. To this end the proper sizing, cleanliness, placing, and the durability of the medium are of utmost importance. The first three of these factors can be controlled while the fourth can be predetermined with a sufficient degree of accuracy from soundness tests. Twenty sodium sulfate cycles with stone, slag and gravel aggregates indicate sufficient durability for satisfactory service as sewage disposal media. Many beds are now operating successfully in which the material will not withstand 20 cycles. The usually considered physical properties such as hardness, toughness, abrasion, etc., are of minor significance as criteria of the fitness of mineral aggregates in this field. Poor operation of a sewage disposal plant is frequently the cause of inefficient behavior of otherwise satisfactory trickle or contact beds.

Acknowledgment.—The above is a paper presented in the "Symposium on Mineral Aggregates" at the 32nd Annual Meeting of the American Society for Testing Materials, Atlantic City, N. J., June 24 to 28.

[1] U. S. Department of Agriculture Bulletin 1216, p. 8 (1924). Revised form, p. 206 (1928).

Sewage Treatment by Stream-Flow Aeration

An Improvement in the Activated Sludge Method

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FOLLOWING various preliminary conferences, an agreement was effected during March, 1927, between Jacob E. Decker & Sons, of Mason City, Ia., and the engineering experiment station, Iowa State College, Ames, Ia., whereby a cooperative industrial fellowship was established for conducting packing-house waste disposal investigations and research. The writer assumed active charge of the project, to collaborate in the solution of the biological and sanitary engineering problems that presented themselves. Frederick G. Nelson, sanitary engineering graduate of the University of California, was appointed research fellow, in charge of field work at Mason City. Dean Anson Marston, as director of the engineering experiment station, has general supervision of all projects undertaken by the station.

Some time previous to the initiation of this project, the Executive Council of Iowa had taken mandatory action to secure the abatement of gross nuisance resulting from the discharge of industrial waste into Lime Creek, this action being based on the recommendations of the Iowa State Department of Health subsequent to a stream pollution survey completed by the division of sanitary engineering. The degree of treatment to be given the wastes was prescribed and a date fixed by which the Decker company, as one of the chief industries affected by the order, should comply with the new regulations. In order to determine by what means, if any, the proposed standard might be reached, either by a modification of the design and operation of the present activated sludge plant, or by some other process or combination of processes, the Decker company availed itself of the services which the engineering experiment station is in a position to render in such cases, through cooperative research in industrial wastes treatment.

During the course of their investigations relating to the Decker problem, the writers originated and studied experimentally a new means of sewage aeration, in an endeavor to ascertain the suitability of the activated sludge process under the best possible operating conditions. Because the new method simulates more closely than any other the basic phenomena responsible for the natural self-purification of sewage-polluted streams, it has seemed appropriate to designate it as a "stream-sewage treatment process." Systematic studies, both in the laboratory and in the field. have demonstrated the fact that, in practical operation, the stream-flow principle gives promise of furnishing an improved means of treating sewage and other organic wastes, as viewed from the standpoints of efficiency and of decreased cost of construction and operation.

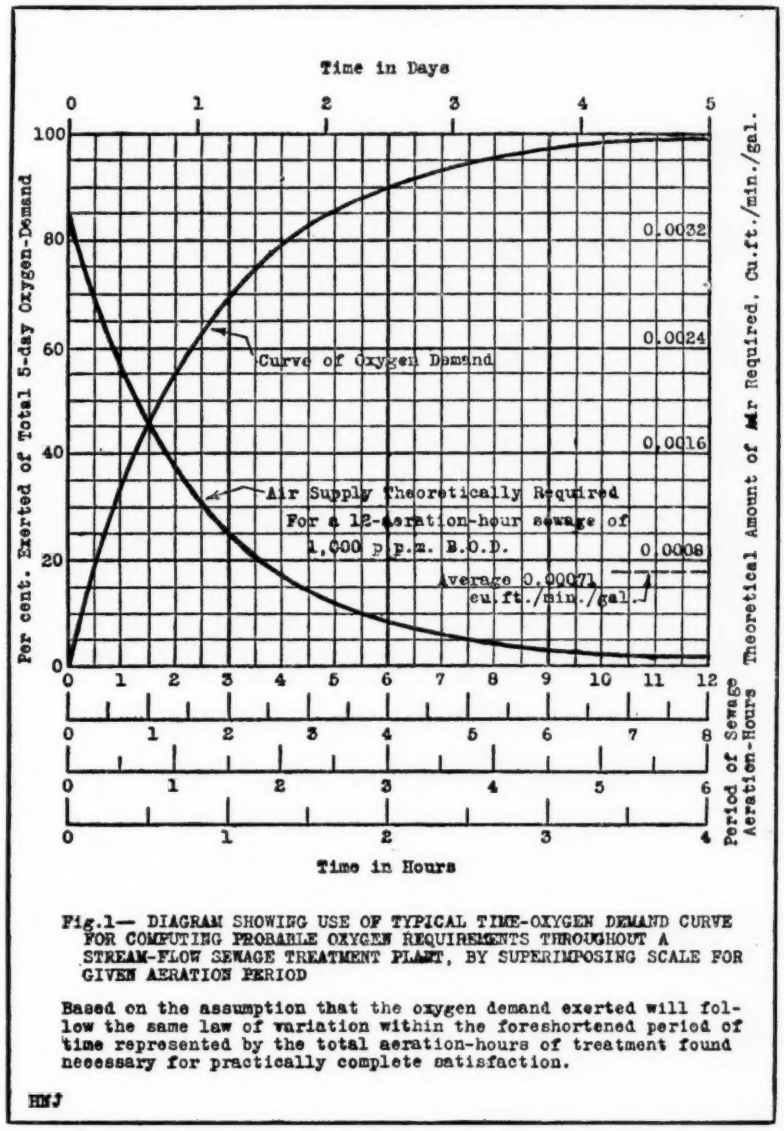


Fig.1— DIAGRAM SHOWING USE OF TYPICAL TIME-OXYGEN DEMAND CURVE FOR COMPUTING PROBABLE OXYGEN REQUIREMENTS THROUGHOUT A STREAM-FLOW SEWAGE TREATMENT PLANT, BY SUPERIMPOSING SCALE FOR GIVEN AERATION PERIOD

Based on the assumption that the oxygen demand exerted will follow the same law of variation within the foreshortened period of time represented by the total aeration-hours of treatment found necessary for practically complete satisfaction.

HMJ

Fig. 1

Contrasts and Similarities in Aerobic Sewage Treatment.—When sewage is treated aerobically, the chief purpose of whatever process may be adopted is to bring the sewage and oxygen into intimate contact with each other. The present high regard in which the trickling filter is held is due in large measure to the effectiveness of this treatment device in maintaining aeorbic bichemical reactions resulting in a high degree of purification at relatively low operating cost. In the trickling filter the active biologic agents concerned in purification are in the form of a thin film which attaches itself to the filter material. As long as any given portion of this film remains in the filter bed it is stationary. This fact is responsible for a very important characteristic of trickling filters which manifests itself in the definite zoning of the biologic

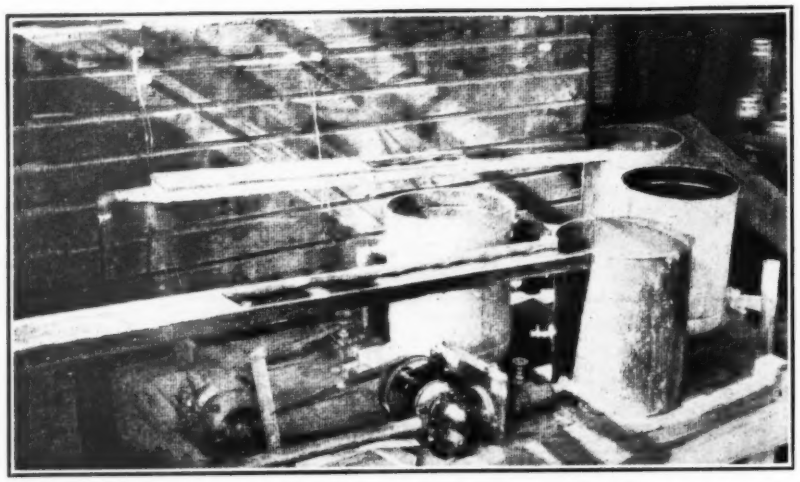


Fig. 2.—Laboratory Stream-Flow Sewage Treatment Plant, Showing Method of Recirculation of Sewage Over Reaeration Surfaces Discharging Into Oxidation Tanks. The Apparatus Is Here Arranged for Biologic Stage Treatment

life within the filter. As the sewage passes downward through the bed, the decomposition products of each stage of purification are successively removed to lower portions of the filter, where these products encounter organisms particularly adapted to the fermentation of such substances. Each zone, therefore, is largely washed free of the end products produced therein, so that these do not interfere with the biologic activity.

In sharp contrast with the trickling filter, the activated sludge process has several inherent disadvantages arising primarily from the fact that the purifying agents must be circulated through the sewage and, as ordinarily carried out, the process does not permit of an orderly biologic zoning, because of the promiscuous mixing of all the living forms that may be present in the activated sludge at any time. These organisms, upon which dependence is placed for the purification of the sewage, are continuously subjected to the inhibitory influences of their own end products until these products are decomposed by other microoganisms, and in each stage of the process the inactive organisms suffer considerable injury. Moreover, it is a difficult matter, when circulating the activated sludge through the sewage, to secure as intimate a contact with the organic matter to be absorbed as is evidently so well effected by the stationary sludge (jelly) adhering to the rock of a trickling filter. Here, also, the active agents are in the form of a thin film, while in the activated sludge process, when the oxygen is brought into the sewage by means of diffused air bubbles, much of the efficiency of surface-film contact is lost.

Finally, when sewage enters a stream and is subjected to the treatment process as evidenced in the self-purification of streams, there succeeds an orderly sequence of stages of oxidation accomplished by the different groups of organisms adapted to the environment present throughout each of these stages. Furthermore, the rate of absorption of oxygen, as defined by the rate of reaeration of the stream, is proportional to the dissolved oxygen deficit, which, in turn, is a reflection of the oxygen demand exerted by the sewage from point to point along the course of flow. In contrast with this situation under natural conditions, the air supplied in the activated sludge process is ordinarily the same in amount from start to finish. The resultant tendency is toward an insufficient supply at the beginning and an excess near the end, or else a waste of air throughout the aeration period.

Conception of Stream-Flow Aeration.—A critical review, such as has been outlined, of the advantages and shortcomings of the principal available methods of aerobic sewage treatment, leads to the conclusion that, in the final analysis, all so-called artificial treatment processes are simply adaptations of those found in nature. Further thought on this subject reveals the close analogy existing between the theory underlying the activated sludge process and the actual biochemical phenomena operative in stream flow.

Although the means which are employed to introduce the required oxygen into the zone of biochemical activity in the activated sludge process are strikingly dissimilar to the absorption of atmospheric oxygen in natural stream flow, yet this contrast is occasioned chiefly by difference in method rather than in principle. Moreover, the relatively short period of aeration, measured in hours, provided in the artificial process, is simply an acceleration of the process of decomposition, extending over a relatively prolonged period, measured in days, throughout which the oxygen demand is being exerted and finally satisfied, in a flowing stream. Taking the natural process as a basis of comparison, it is observed that the advantage lies with the artificial process in respect to the time factor of purification, a result attained by virtue of the presence of the artificially developed activated sludge. On the other hand, it is apparent that in the natural self-purification of streams the direct absorption of atmospheric oxygen without the employment of extraneous mechanical power other than an equivalent small loss of head, coupled with the absorption of such oxygen in proportion to the oxygen deficit only, is a manifestation of the economy of nature which the existing artificial process very imperfectly applies. The truly enormous weight of oxygen appropriated from the atmosphere by streams, through surface reaeration, comes as a surprise to engineers who are aware only in a general way of this phenomenon, and it can not fail to impress any one making the detailed computations required for studies of the oxygen balance in streams.

For some time past, the writers, in common with other workers in this field, have been impressed with the quite evident wastefulness of the present methods of introducing compressed air, through diffuser plates, into the body of sewage passing through the aeration tanks of an activated sludge plant. By waste of air is meant, in the present discussion, the use of air for other than its appropriation by the aerobic organisms for the oxidation of the organic matter. That the amount of air, and consequently the expenditure of power, is greatly in excess of the theoretical requirements for the satisfaction of the oxygen demand is clearly indicated by Fig. 1. On this diagram a curve is drawn showing the air supply theoretically required for an industrial sewage having an initial five-day oxygen demand of 1,000 p.p.m., and is based on the assumption that the rate of satisfaction of this demand will proceed substantially in conformity with the general course of the deoxygenation curve proposed by Phelps and later more fully confirmed by Theriault during the latter's studies on the pollution of the Ohio River.[1] Although deoxygenation in the presence of activated sludge, and the consequent need for oxygen to supply the resulting deficit, may doubtless be found, upon further study, to proceed at numerically different rates than those in the ordinary cases considered; yet the authors have determined that the typical five-day deoxygenation curve quite well defines the general relative magnitude of the oxygen demand during successive periods of time, measured, in the present instance, in hours of aeration. From Fig. 1 it may be observed that the average theoretical requirement for air to remove 99 per cent of the oxygen-demanding con-

[1]Phelps, E. B. (1909): The Disinfection of Sewage and Sewage Filter Effluents. U. S. Geological Survey Water Supply Paper 229, pp. 74-88.

Also Theriault, E. J. (1927): The Oxygen Demand of Polluted Waters. Pub. Health Bull. No. 173, p. 131 et seq.

stituents from a 12-aeration-hour[2] industrial waste of 1,000 p.p.m. initial biochemical oxygen demand is only slightly more than ½ cu. ft. per gallon, whereas the normal use of air in practice might be from 4 to 6 cu. ft. per gallon for such a waste.

Aside from the wide divergence between the theoretical and actual requirements for air for oxidation purposes, the current practice of supplying the same amount of air per unit volume of sewage, from beginning to end of the aeration period, is not in conformity with the fact expressed by Phelps that "the rate of biochemical oxidation of organic matter is proportional to the remaining concentration of unoxidized substance, measured in terms of oxidizability." To take this condition into account requires the introduction of oxygen at the maximum rate at the beginning of the process, followed by a gradual reduction of air supplied, corresponding to the decreasing oxygen demand exerted, until the completion of the aeration period is reached.

Engineering Design of Basis of Stream-Flow Reaeration.—The theory of reaeration and its application to problems of stream pollution encountered in practice have had extensive treatment in current technical literature, notably by Streeter and Phelps,[3] in a classic contribution to our knowledge of the physical factors involved in the self-purification of natural streams. The definite, quantitative relationships discovered by these investigators and formulated mathematically for use in computing reaeration rates furnished valuable collateral evidence as to the correctness of the basic conception for the engineering design of a sewage-treatment plant on the stream-flow principle, presently to be described. In such a plant the oxygen requirements are met through surface reaeration of the sewage under optimum conditions as found in natural water courses.

Streeter's investigation showed that the rate of reaeration, designated by him by the symbol, K_2, is defined mainly by the temperature, oxygen saturation deficit, and the turbulence of the stream. In a sewage-treatment plant employing the stream-flow principle it was conceived that the factor of turbulence should be brought into play to the best possible advantage. Turbulence itself being an abstract characteristic, Streeter defined it in terms of velocity and depth, and determined empirically the validity of the following relationship:

$$K_2 = \frac{cV^n}{H^2}$$

where K_2 = coefficient defining the rate of reaeration;
V = velocity of the stream in feet per second;
H = mean depth of flow in feet;
c = constant depending chiefly upon irregularities in different stream stretches, producing turbulence; and
n = constant defining the variation in reaeration rates in the same river stretch for different flow conditions.

In analyzing the numerical values of (n), Streeter found that, when the channel conditions are such that a 5-ft. increase in stage produces from 2 to 7 ft. per second increase in mean velocity, little change in the value of (n) occurs, its actual value at the upper end of the velocity range being slightly greater than unity. In such a case the influence of the velocity itself predominates over that of turbulence.

Regarding the values of (c), it was concluded that the slope and irregularity of the channel are probably the governing factors. Available data on the Ohio River tend to show that the irregularity factor itself loses most of its effect when the slope approximates 2 ft. per mile. With greater slopes than this, corresponding values of (c) increase at a much more rapid rate.

In concluding his analysis of the factors influencing the value of K_2, Streeter shows that there is a "tendency for K_2 to reach a maximum with increasing velocities of flow up to a certain point. * * * The velocity of flow coinciding with this maximum K_2 point varies in different river stretches studied, but in a majority of them it is reached at somewhere between 2 and 4 ft. per second."

Holding in review the conclusions set forth by Streeter and his collaborators in relation to stream-flow aeration, it is apparent that this natural phenomenon can be directly applied to the treatment of organic wastes by providing an engineering design in which the maximum value of K_2 should be obtained. This object may be reached by means of a controlled section of stream channel in which the proper depth and velocity can be maintained. In natural streams the decomposition of the sewage proceeds over a long course of flow, many miles in length, so that it was recognized that within the physical limits of a treatment plant the necessary time element, in terms of distance traversed, could not be introduced in this way. Accordingly, recirculation of the sewage over the controlled section was decided upon and the design of the plant was made in accordance with the following basic assumptions:

(1) The rate of biochemical oxygen satisfaction will proceed, in the presence of activated sludge, substantially in accord with the deoxygenation curve as derived for flowing streams, except that the biochemical oxygen demand will be fully exerted and satisfied within a foreshortened period of time. (See Fig. 1.)
(2) The effect of reaeration may be closely simulated by exposing the sewage flow in thin sheets to the atmosphere by recirculation over a reaeration surface comprising a controlled stream section distinctly separate from the zone of biologic activity wherein the oxygen so absorbed is utilized.
(3) The rates of recirculation of sewage over the reaeration surfaces at different points throughout the aeration period shall be adjusted to the actual biochemical oxygen demand correspondingly exerted.

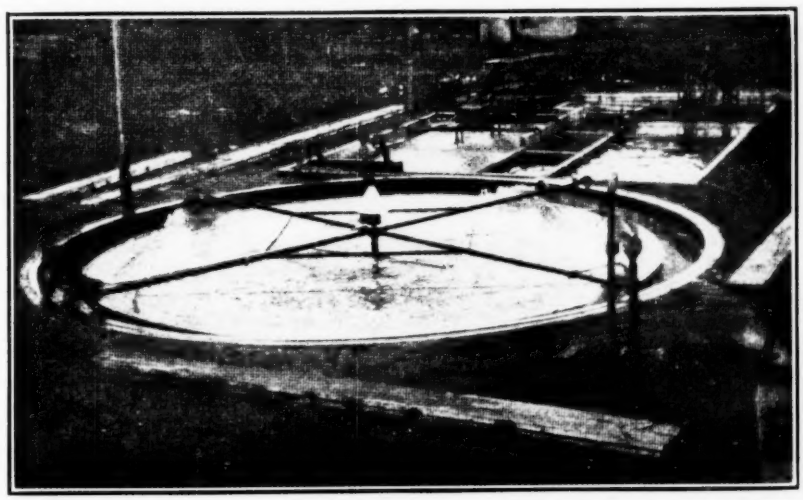


Fig. 3.—Practical Scale Field Installation of Stream-Flow Plant for Treatment of Packing House Wastes. General View of Reaeration Units and the Types of Pumping Equipment Devised for Test Purposes

[2]The term "aeration hours" refers here to the ascertained period of aeration needed to effect the maximum reduction of biochemical oxygen demand of which the process is economically capable when treating the sewage in question. Thus, a sewage requiring six hours' aeration for satisfactory treatment on this basis, may be referred to as a six-aeration-hour sewage.

[3]A Study of the Pollution and Natural Purification of the Ohio River. Public Health Bulletin No. 146, U. S. Public Health Service (1925).

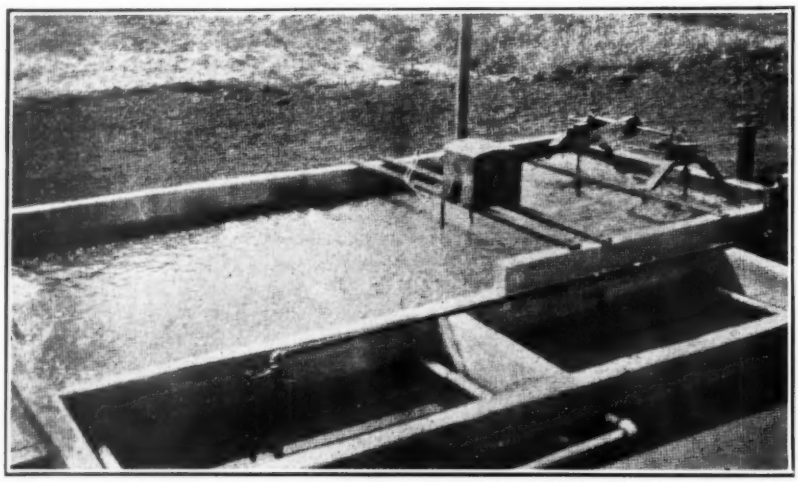


Fig. 4.—View of Primary Stage Aeration Unit of Practical Scale Stream-Flow Sewage Treatment Plant, Showing the Realistic Manner in Which the Recirculation of the Sewage Over the Reaeration Surfaces (to the Right) Simulate the Rills and Riffles of a Rapidly Flowing Shallow Stream. Illustration Shows Propeller Blade Pumps in Operation in This Unit

The physical construction which a stream-flow plant thus assumes was seen to involve essentially a biochemical oxidation zone contained in a tank or basin through which the main body of sewage progresses and a separate reaeration or oxygen-absorbing zone, embodied in a paved surface adjacent to or over the tank, over which an independent and concomitant recirculation of the organic wastes is maintained. The sewage is withdrawn from the oxidation zone, discharged onto the reaeration surface, and allowed to flow down the slope of this surface, thence returning into the oxidation zone within the aeration tank.

In comparing the stream-flow plant design conditions with the relationship $K_2=cV^n/H^2$, it will be noted that the minimizing effect of (H) may be practically eliminated by making the depth from 0.5 to 1 in., thus presenting the maximum surface practicable for a given volume of sewage recirculated over the reaeration surface. The desirable velocity of flow over this surface to prevent deposition of sludge was assumed to lie between 2 and 3 ft. per second, which corresponds closely with the range found by Streeter to be conducive of maximum values of the reaeration coefficient K_2. It has been determined that a slope of ½ in. per foot will give closely the desired velocity, even when transverse cleats are placed in the reaeration channel to induce riffling. As this slope is greatly in excess of the 2 ft. per mile, above which point the value of (c) increases most rapidly, the effect of such a slope is very favorable to increased values of K_2. Finally, as regards (n), in a channel of the type under consideration the hydraulic radius increases rapidly with increased depth, so that the velocity effect itself predominates, with a value of (n) close to unity; this is also true on account of the negligible effect of the depth (H). The conditions of flow, therefore, in a stream-flow plant are the counterpart of a natural stream progressing through a long series of riffles and pools, a condition known to be most favorable to self-purification within a minimum distance, measured in time.

Installation of Practical-Scale Stream-Flow Plant.—After the stream-flow idea had been given a thorough preliminary trial with the laboratory apparatus shown in Fig. 2, operating on milk wastes up to 2 per cent concentration and yielding results presented at a later point in this article, a practical-scale field plant was constructed at the Decker packing plant. Fig. 3 is a photograph of this installation, showing the general arrangement of the plant and types of pumping equipment employed for test purposes. Fig. 4 is a view of the second aeration unit (tank B indicated in the flow sheet of Fig. 5), taken to illustrate the realistic manner in which the recirculation of the sewage simulates the rills and riffles of a rapidly flowing shallow stream.

The structural features of a stream-flow plant, except for the aeration units, conform in essential particulars to the general design followed in the case of the activated sludge process. That is, a complete installation might comprise preliminary settling tanks, or screens, and final sludge settling tanks, together with appurtenances, in addition to the stream-flow aeration units themselves. As there is nothing in the aeration units to become clogged, whatever removal of suspended matter may be effected will be done to lessen the biochemical oxygen demand of the influent, or to recover such organic solids as may be utilized in the by-products department of the industrial plant producing the wastes. The provision of pretreatment by sedimentation thus becomes a matter of economics rather than one of necessity.

Effect of Recirculation on Retention Period.—In practice, circumstances will dictate as to the position of the inlets and outlets of the various tanks or basins and of the recirculation piping. Because of the removal and return of the sewage flow as it passes through each of the oxidation tanks or the various compartments of a single tank, it is evident that there will be an indeterminate amount of short-circuiting of the tank contents from inlet to outlet. The crude or average retention period is computed on the actual displacement basis, although in fact the aeration period of successive volumes of flow is variable.

The situation with reference to effects of short-circuiting may be regarded as analogous to that which prevails in regard to the flowing-through period in mechanically operated mixing tanks. This matter was thoroughly investigated in connection with the design of the coagulation tanks for the Sacramento, Calif., filtration plant under the direction of Charles G. Hyde, chief consulting engineer, and based on the original research work of W. F. Langelier. Professor Langelier concluded from experiments[4] that the probable under-treatment due to short-circuiting may be expressed by the formula

$$X = 1 - [1 - (1 - R/Q)^{t/n}]n$$

Where Q = capacity of each tank in gallons;
R = flow of water (gallons per minute);
n = number of tanks;
t = minutes actual retention in n tanks;
X = proportion of water remaining in tanks t minutes (or longer).

The formula is based on the assumption of practically instantaneous diffusion of incoming water with tank contents.

Curves based on the foregoing expression show that when there are two or more tanks, short-circuiting is greatly reduced, the number of tanks having a much greater effect than their capacity in obviating undertreatment due to short-circuiting. From actual operating experience at the plant mentioned, Jenks found that the proportion of total flow escaping adequate coagulation, or its retention equivalent, is negligible when three or more tanks are operated in series. It is concluded that similar results are to be expected from the aeration units of a stream-flow plant.

Pumping Equipment for Reaeration.—The manner of maintaining the auxiliary recirculation of the organic wastes through the reaeration system, as the main body of sewage progresses through the oxidation tank, is a matter to be decided upon the basis of convenience and cost. It will be recognized that the pumping problem here is

[4]Coagulation of Water with Alum by Prolonged Agitation. Eng. News-Record, vol. 86, No. 22, pp. 924-928 (1921).

a most unusual one, involving as it does the discharge of relatively large volumes of sewage against an extraordinarily low static head, amounting to perhaps not more than 4 to 6 inches. Of the standard forms of pumps, the screw pump offers one of the best means of meeting these operating conditions at a reasonable efficiency. Such a pump might, however, be unduly expensive when designed specially for an extremely low head. Accordingly, three special pumping mechanisms, such as might be fabricated in a local machine shop, were devised for the Decker experimental field plant. Tank A was provided with a plow pump; tank B with a propeller pump; and tank C with a plunger box pump. The general view of the plant, shown in Fig. 3, indicates these devices in operation. Their suitability for this service is being studied comparatively to determine which design might be used most advantageously.

Plant-Operating Data.—The operating results obtained from the stream-flow plant are based on an extensive series of tests, with the laboratory-sized plant (Fig. 2), on milk wastes, packing-house wastes, and sugar-beet wastes. The satisfactory treatment of these wastes from the standpoint of biochemical oxygen demand reduction, development and maintenance of an excellent activated sludge, and elimination of acid-producing constituents, led to the design and construction of a practical-scale field plant at the Decker packing plant. This installation enables a study to be made of the mechanical, hydraulic, and general engineering features of the new design.

Aeration Efficiency.—The efficiency of the stream-flow principle of aeration has been shown to be consistently as good as that of diffused air when treating the industrial wastes already mentioned. Illustrative of the results obtained on packing-house wastes (Decker), Table 1 is presented, which shows the reduction in biochemical oxygen demand after various aeration periods. The data are based on six weeks' operation, and the results are listed in the order of their occurrence. It will be noted that although the wastes being treated may be considered a 12-aeration-hour sewage, yet a remarkable reduction in b.o.d. occurs after only 6 hours' aeration.

As to comparative efficiency of stream-flow aeration, it is believed that the continual exposure of the sewage to the atmosphere, as it flows over the reaeration surfaces in thin films, more closely approaches the optimum conditions for oxygen absorption than any design heretofore proposed.

Effect of Biologic Staging.—The division of the treatment process into two or more stages, developing and maintaining a distinctly separate activated sludge for each stage, was conceived as a means of favoring increased biologic efficiency on the basis of the considerations relating to biologic zoning of trickling filters, as discussed at the beginning of this article. That this reasoning is essentially correct is evidenced in part by the results of stage treatment given in Table II showing that nitrification was secured by this means when treating 2 per cent milk waste by stream-flow aeration units. It may be noted that whether a primary stage of 6 hours was succeeded by a secondary stage of 18 hours, or the process reversed, nitrification for this type of waste ensued. In contrast with these results, Levine showed in previous research on the treatment of milk wastes that even with an unlimited supply of diffused air it was impossible to produce nitrates in single-stage treatment by the activated sludge process.[5]

Although the writers are aware that some engineers may be of the opinion that stage treatment does not commend itself on economic grounds for domestic sewage, yet they are convinced that biologic stage treatment merits serious consideration as an important aid in enhancing the efficiency of the activated sludge process where the more concentrated industrial wastes are concerned. This conception of the logical and proper method of operating an activated sludge plant is being given further study in the field stream-flow plant at Mason City. It appears that at least one important point that has heretofore not been adequately emphasized is the great advantage of removing as quickly as possible, from the aeration tanks, all excess sludge with its own high oxygen demanding characteristics gained by absorption from the wastes being treated. This can be accomplished by intermediate settling between stages, and so lessen the oxygen demand of succeeding stages. To take advantage of this fact, the Decker practical-scale stream-flow plant provides stage treatment in accordance with the flow sheet shown in Fig. 5.

Table I.—Reduction in Biochemical Oxygen Demand Effected by Laboratory Stream-Flow Aeration Unit, on Packing-House Wastes

(Based on plant operation during period July 14-Aug. 27, 1927)

Biochemical oxygen demand p.p.m., raw wastes[1]	Biochemical oxygen demand p.p.m.,[2] after indicated aeration period, in hours: 6	12	18	22
1,000	300	65	60	120
1,180	....	115	95	90
700	80	40	40	50
1,100	43	18	20	28
820	56	33	33	30
925	44	25	26	26
600	32	98	70	45
650	38	30	30	59
550	52	13	34	....
1,225	40	74	79	73
1,300	48	33	27	47
1,050	106	110	28	....
2,000	132	69	56	....
Median value, 1,000	50	40	34	55
Apparent Satisfaction of Initial Demand, Per Cent[3]	95	96	97	94

[1]Settling-tank effluent.
[2]5-day biochemical oxygen demand at 20° C.
[3]Demand after various aeration periods taken on supernatant liquid; actual percentage satisfaction of demand should take into account transfer of oxygen-demanding substances to the activated sludge.

Power Requirements for Stream-Flow Aeration.—It can be shown by computations based on the deoxygenation curve described in a previous section of this article, and corroborated substantially by experiments, that a packing-house waste such as that found at the Decker plant and referred to in Table I can be treated by the stream-flow method through 12 hours' aeration, involving the recirculation of approximately 125 times the volume of sewage flow. Similar methods of computation applied to the case of a domestic sewage containing some industrial wastes, resulting in a biochemical oxygen demand of 350 p.p.m., should be successfully treated through six-hour stream-flow aeration of 50 times the volume of flow. For the latter case, assuming conservatively a lift of 4 in. and an over-all pumping efficiency of 25 per cent water level to water level, the required energy for aeration should not exceed 12 hp. per m.g.d. treated.

It is realized that only actual operating experience with a full-sized installation can demonstrate the correctness of such a power estimate. Yet, the order of magnitude of the power required is such that a considerable factor of safety might be introduced without seriously detracting from the favorable comparison that can be drawn between the stream-flow plant and existing means of sewage aeration. In fact, if sufficient difference in elevation exists at the treatment-plant site, it is possible to design the plant in such a manner as to obviate a substantial part of the recirculation pumping through

[5]Iowa Engineering Experiment Station Bulletin No. 68, p. 27.

Table II.—Changes in Nitrogenous Constituents Obtained by Aerating 2 Per Cent Skim Milk

Constituent	Aeration by Diffused Air, May 15 to June 7, 1922[1]: Raw waste	Effluent after 21 to 45 hours' aeration	Stream-Flow Aeration: Raw waste, May 31 to July 5, 1927	23-hour continuous aeration	6-hour primary, 18-hour secondary	18-hour primary, 6-hour secondary	6-hour primary, 6-hour secondary
Org. N	102.5	9.08	72.6	19.7	7.55	10.65	11.25
NH_3	1.70	12.70	1.4	.35	13.12	12.08	1.75
NO_2	.05	.01	.044	.01	5.38	5.07	3.8
NO_3	1.38	.12	1.38	.50	2.39	2.03	2.6

[1]See Iowa Engineering Experiment Station Bulletin 68, p. 27.
Notes.—23-hour continuous aeration based on tests, May 31 to June 2, 1927.
6-hour primary followed by 18-hour secondary, June 5 to June 24, 1927.
18-hour primary followed by 6-hour secondary, June 5 to June 24, 1927.
6-hour primary followed by 6-hour secondary, June 28, to July 5, 1927.

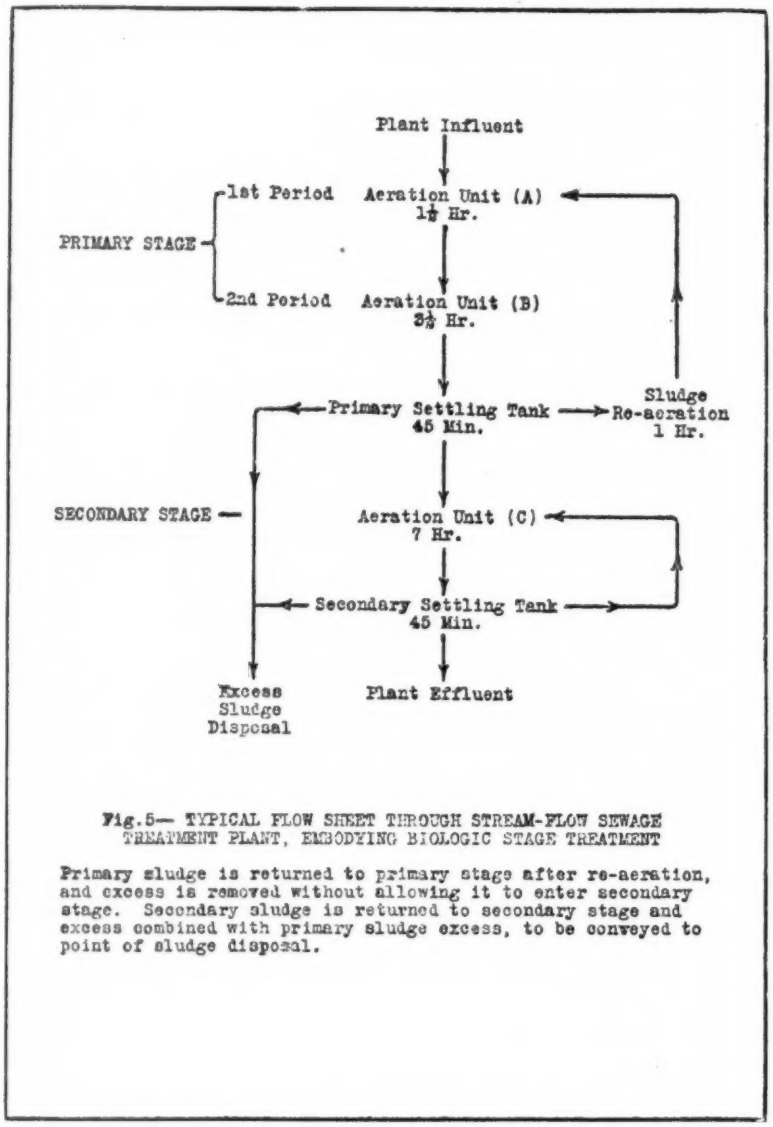


Fig.5— TYPICAL FLOW SHEET THROUGH STREAM-FLOW SEWAGE TREATMENT PLANT, EMBODYING BIOLOGIC STAGE TREATMENT

Primary sludge is returned to primary stage after re-aeration, and excess is removed without allowing it to enter secondary stage. Secondary sludge is returned to secondary stage and excess combined with primary sludge excess, to be conveyed to point of sludge disposal.

Fig. 5

the utilization of this available head. In such an event the conditions of aeration would closely approximate those found throughout the course of a natural stream bed.

Cost of Construction.—In the construction of a stream-flow plant it will be observed that it may be built so as to require relatively little excavation. In general, if excavation costs are high in comparison with the cost of area of land covered by the plant, then the tanks may be made quite shallow. For small plants it is suggested that the depth may be 4 to 6 ft. No dependence upon depth is required to provide a proper contact period of the air with the organic matter, which is a practical necessity in the diffused-air activated sludge aeration tank. The operation of the tanks entails the usual low loss of head resulting from flow through unbaffled basins at low velocities.

The stream-flow absorption of atmospheric oxygen insures an adequate oxygen supply without any expense for installation and operation of air piping and diffuser plates. Also, in comparison with air-washing and air-compressing equipment and machinery used in diffused-air plants, the extremely low-head pumping equipment and simple piping alone needed in the stream-flow plant is far less expensive, both in first cost and in operation.

It is suggested that for a plant to treat, say, 2 m.g.d., the first tanks might be provided with screw pumps discharging from 6,000 to 8,000 g.p.m. each. In the last tanks, where the recirculation rate is greatly reduced, plunger-box pumping units might be employed, operated by a common roller-bearing crank shaft, along each side of the tanks. In connection with studies of pumping requirements, an apparatus of unique design is being tested, by which advantage may be taken of the very low lift to utilize effectively the velocity head created by the pump impeller, operating on the vortex principle.

The reaeration surfaces may partly or wholly cover the aeration tanks or be laid as a pavement on natural ground along the edge of the structures. If the oxidation tanks are made of conventional depth, then the stream-flow aeration units will occupy very closely the same area as aeration tanks designed in the ordinary way. This is an important point which has been rightly emphasized by Streeter in discussing the relative economy of area required by various aeration devices typical of British sanitary engineering practice.[6] Experiments indicate that the reaeration surfaces should be from 6 to 10 ft. in length, providing three to five seconds' exposure of the sewage film to the atmosphere at 2 ft. per second velocity. A design factor will be determined empirically which will give the permissible recirculation rate in g.p.m. per square foot of reaeration surface. If required by severe weather conditions, the reaeration surfaces may be readily covered, air being admitted through suitably spaced ventilators.

It is not possible within the scope of this article to review the results obtained by other investigators in the field of sewage aeration by mechanical agitation, in order to point out the essential similarities and differences between stream-flow aeration and that secured by other means. It is the authors' hope that, after they and others who will become interested in this subject have fully overcome the difficulties that will naturally be encountered in the practical application of so novel a form of sewage-treatment plant, it will become a fitting engineering counterpart of the notable advances made by British engineers in the use of mechanical aeration in the activated sludge process.

It gives the authors pleasure to acknowledge at this time the very gratifying cooperation of the Jacob E. Decker & Sons organization, particularly on the part of Jay E. Decker, president, E. S. Selby, treasurer, and Elmer E. Dye, chemist of that company. Acknowledgment is also due all members of the engineering experiment station staff who have been interested in the furtherance of this project, among whom Harry E. Goresline, assistant bacteriologist, and George W. Burke, chemical engineer, have rendered valuable assistance in the laboratory work. Credit is also due Robley Winfrey, assistant director, for his helpfulness at all times in arranging the necessary financial and organization details of the project.

Acknowledgment.—The above article is taken from the Sept. 28 Public Health Report.

[6]Streeter, H. W., in Pub. Health Bull. 166, pp. 28-29.

Selecting Material for Earth Dam

Methods Employed for Granville Dam, Westfield, Mass.

By CHARLES TERZAGHI

Professor of Foundation Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

THE information obtained by exploring the proposed borrow-pit area on the left side of the dam was sufficient to show that by far the most suitable dam-construction material is located above elevation 560 (more or less) on top of the deposit of reddish sand.

By excavating additional test pits we learned that the composition of the deposit in the borrow-pit area is almost as variable as the composition of all the other deposits found in the vicinity of the dam site. Thus the question arose as to how we should determine during construction whether any newly-opened section of the borrow pit would furnish material with a sufficiently low average coefficient of permeability to permit its use. Since by necessity tests are restricted to samples selected at random, while the coefficient of permeability is apt to change from foot to foot, it seemed preferable to obtain approximate results for a great number of samples rather than accurate results for a few.

Method of Estimating Coefficient of Permeability.—To reduce the time and labor required for estimating the coefficient of permeabiliay of samples, we developed a method based on the fact that the speed of capillary rise of water through soil becomes less as the soil is less permeable. The theory of the process is somewhat complicated, because the speed of upward movement depends not merely on permeability but also on the ultimate height of the water level. Due to this complication there merely exists an approximate proportionality between the speed of capillary rise and the reciprocal value of the coefficient of permeability. A further complication is introduced by the fact that some air is retained within the voids of the soil while the water moves upward. Nevertheless, the fact remains that the steepness of the curve, which represents graphically the speed of capillary rise, increases with the permeability of the material. Figure 1 shows curves for those samples whose permeability was accurately determined. By observing the capillary upward movement for any sample and by plotting the results on Fig. 1, one can roughly estimate the coefficient of permeability of the material.

Testing Device and Procedure.—The device for making the tests is shown in Fig. 2. It consists of a simple tank (A) made of sheet tin, an irrigator for feeding the tank, and a set of glass tubes (G), made of hard glass. Hard glass is essential, otherwise the cylinders invariably break during the tests. The bottom of each glass tube is covered with a brass wire screen stretched across and soldered to a brass ring. In order to test a sample, the procedure is as follows:

The sample is dried on a stove, after which it is placed in one of the glass tubes, in layers 2 cm. thick, until the cylinder is completely filled. Each layer is compacted by lifting and dropping ten times from an elevation of 4 in. a cylindrical pestle made of hard wood, with a diameter of 1¼ in. and a weight of 150 grams. In case the sand grains are smaller than the openings of the sieve, a 2 or 3-mm. layer of coarse sand is placed on the sieve before the first layer of the sample is introduced. In the meantime the tank is filled with water supplied from the irrigator, the excess water passing over the crest of the overflow (W) and draining away through the discharge pipe. As soon as the cylinder is filled with the sample, the brass sieve is wetted with a mist cloth and the cylinder is placed on the immersed support (S), as shown in Fig. 2. Care should be taken to keep the cylinder in a slightly inclined position while lowering it through the surface of the water so as to offer a chance for lateral escape of air.

As soon as the base of the glass cylinder touches the surface of the water, the water starts to rise by capillary action within the sample, as indicated by the color of the sample turning dark. The smaller the permeability of the sample, the slower is the upward movement of moisture. Readings of the rise in water level are taken 5, 10, 20 and 30 minutes after the test is started. The simplicity of the necessary operations permits six tests to be carried on simultaneously.

Observation During Construction.—After the report on the soil studies was presented, the underground strata were exposed to direct inspection by the construction of the core trench and the excavation of the borrow pits. It was found that the underground conditions checked with the predictions. The right (southern) wing of the dam rests against a very feeble permeable portion of the south slope. The permeability of the material from the borrow pit averages, according to the results of the capillary tests, 0.000068 cm. per sec., which is below the value of 0.0001 cm. per sec., on which seepage computations were based. The layer of boulders, which covers the bottom of the valley is strictly confined to the area between the slopes. Although the material was found to be very compact, the core wall was constructed so as to prevent subterranean erosion along individual seams or channels. The bed rock was more badly shattered than was expected from the drilling records; as a consequence it had to be grouted.

In order to exclude borrow-pit material that is more permeable than we intended to tolerate, a curve (k) was traced on Fig. 1, corresponding to the capillarity curve of a material with a coefficient of permeability of 0.0001 cm. per sec., on which the estimate of seepage losses was based. From time to time, particularly in case a stratum of doubtful quality was encountered, samples were tested by means of the

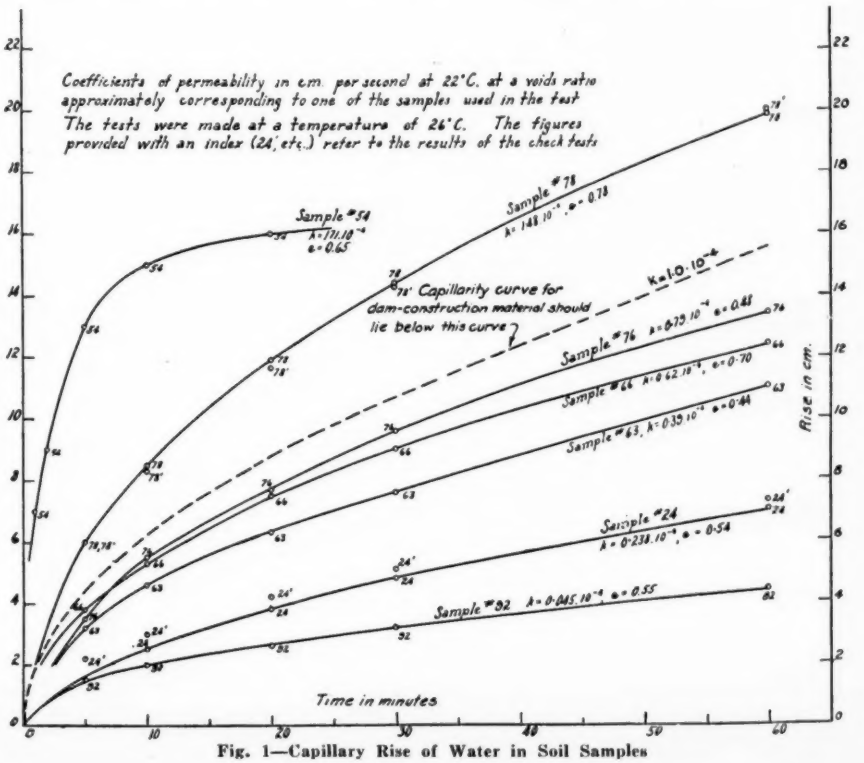

Coefficients of permeability in c.m. per second at 22°C. at a voids ratio approximately corresponding to one of the samples used in the test
The tests were made at a temperature of 24°C. The figures provided with an index (24', etc.) refer to the results of the check tests
Sample #54
Sample #78
Capillarity curve for dam-construction material should lie below this curve
K=1.0.10⁻⁴
Sample #76
Sample #66
Sample #63
Sample #24
Sample #92
Time in minutes
Rise in cm.

Fig. 1—Capillary Rise of Water in Soil Samples

apparatus shown in Fig. 2, with the intention of excluding from use in the dam any material whose capillarity curve is located above curve (k). The material in which the steam shovel worked, was more or less stratified, but when it broke off the bank and was picked up by the shovel, it became well mixed so that the samples taken from the trucks were fairly representative.

Testing Embankment Material.—During construction, two questions arose concerning methods for testing embankment material: First of all, whether or not the drying of the material in the stove has any influence on the results of capillarity tests and second, whether the volume of voids of the material in the embankment is smaller or greater than the volume of voids obtained when compacting the material in the standpipe of the capillarity apparatus. Due to the great influence of the volume of voids on permeability, the second question was of vital importance.

Concerning the first question, we found that the drying process had no appreciable effect on permeability, inasmuch as the tests with air-dried and with stove-dried sample gave practically identical results. In order to answer the second question, undisturbed samples were secured from a pit excavated in the finished embankment. Excavation of the pit was difficult and required the use of pick and shovel, which demonstrates the excellent results obtained by compacting with Caterpillar tractors. Due to the presence of many stones in the fill, a cylindrical sampler with cutting edge could not be used. Hence, large chunks of soil (up to ¼ cu. ft.) were removed and sealed on the ground by repeatedly painting their surfaces with hot paraffin. In the laboratory the volume of the sealed chunks was determined by immersing them in water. Afterwards the chunks were skinned and the original and dry weight of the chunks and the specific gravity of the solid constituents were determined. From these data was computed the volume of voids of the more fine-grained mass that filled the interstices between the stones. This volume of voids was found to be equal to 26 per cent of the total volume. Finally, the more fine-grained material was transferred into a permeameter, and the permeability was determined in a loose and in a compacted state. At this time we learned that it was practically impossible to bring the density of the material in the permeameter, by ramming it in a moist condition, up to the density of the material in the embankment. Figure 3 shows the test results. These indicate that permeability decreases with decreasing voids-ratio much more rapidly than one would expect. This was due to the appreciable mica-content of the sample. From previous experience we know that the finer the soil and the greater the percentage of scale-like particles, the steeper is the voids-ratio-permeability curve. Figure 3 also shows that the voids-ratio of the sample compacted in the standpipe of the capillarity apparatus is considerably greater than the voids-ratio of the material in the embankment (0.464 against 0.366). Hence, the factor of safety against excessive percolation is ample when computations are based on the results of capillarity tests.

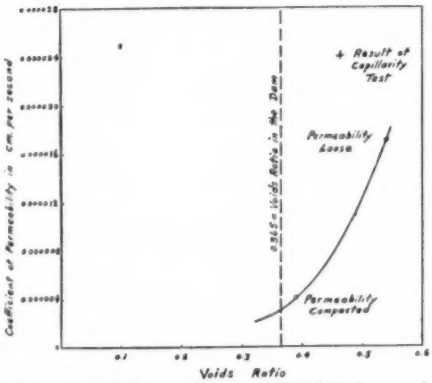
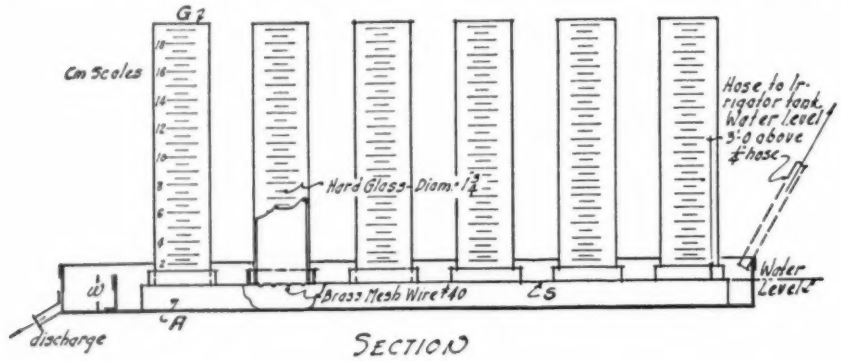
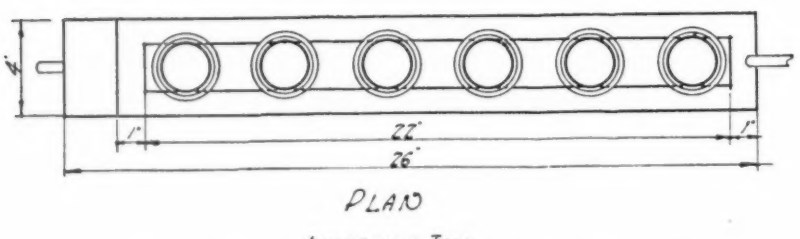


Fig. 3—Relation Between Void-Ratio and Permability of Loose and Compacted Soil

The method of keeping track of the quality of the dam-construction material by means of capillarity tests was found to be satisfactory except in so far as the relation between permeability and the speed of capillary rise depends to a certain extent on the character of the sand grains and silt fraction. For this reason two materials with equal permeability are apt to have two somewhat different capillary-rise curves, and a set of curves similar to those in Fig. 1 cannot be depended upon except for the same class of materials. In order to eliminate this shortcoming, modifications of the testing procedure are under consideration.

Acknowledgment.—The above is an extract from a paper in the June issue of the Journal of the New England Water Works Association.





IMMERSION TANK.

Fig. 2—Device for Observing Capillary Rise of Water in Soil

Serious Water Famine in England

Press dispatches from London, under date of July 17, state that England is suffering from a very serious water famine due to lack of rainfall. Official appeals for the most rigid economy have been made nearly everywhere in the largest cities and in the smallest villages. The situation is critical for households and industries.

So serious have matters become in the woolen mill district of Yorkshire that general restrictions have been introduced. On the above date Dewsbury had only a twelve hours' a day service and thirty-one days' supply, while the neighboring town of Batley had only fifteen.

Conditions are serious in the villages surrounding Oxford. In the Crown Marsh rural area water must be carried in barrels half a mile. At St. Eventon in Berkshire there is a supply only on alternate days, while at Milton the supply has been cut off between 1 in the afternoon and 8 in the morning.

Unless rain falls soon, Boston will be faced with a repetition of the 1921 water famine, when supplies had to be brought from Willoughby by rail. The brook at Miningsby, Boston's regular source of supply, dried up three years ago, leaving the town dependent on the waterworks company's single reservoir.

Throughout the country warning notices have been posted and handbills have been distributed requesting the public to be careful in the use of water and to refrain from watering gardens and washing automobiles.

Recent Developments in Water Works Field

Abstracts of Papers Presented at Toronto Convention of American W. W. Assn.

Manganese Dioxide Deposits in Catskill Aqueduct

The Cause and the Proposed Remedy

By FRANK E. HALE
Director of Laboratories, Bureau of Water Supply, New York City

THE Catskill aqueduct from Ashokan reservoir to Kensico reservoir was first put into service late in 1915 to serve a portion of the Bronx. Early in 1917 the full available quantity of water from Esopus Creek was brought down to supply portions of all boroughs of New York City. Chlorination at Ashokan headworks was placed in regular operation January 10, 1925. On December 11, 1924, the flow of water in the aqueduct was increased to maximum capacity, approximately, due to the fact that a portion of the Schoharie development became available. In the aqueduct there is visible evidence of the average flow of water at two levels representing about 400 m.g.d. and 600 m.g.d.

1 In. Deposit Formed.—It was noted that a brown deposit formed on the walls of the aqueduct up to the original water level and that this deposit exercised considerable influence upon the amount of water flowing through the aqueduct. The deposit reached as much as 1 in. in thickness near Ashokan reservoir, prior to chlorination.

The increased flow in the aqueduct and chlorination were introduced at about the same time. Following chlorination the deposit reduced in thickness, became detached in large areas, and less effect was noted on the available capacity of the aqueduct. The matter seemed of sufficient importance to ascertain the character of the deposit, its distribution, the extent and reason for the influence of the chlorination, with a view to ascertaining whether the introduction of additional chlorination at intervals and at points further down the aqueduct would be feasible and desirable for the purpose of increasing the available capacity of the aqueduct.

Consequently the aqueduct was emptied and inspected on Oct. 8, 1928, between Ashokan and Kensico reservoirs at numerous points and samples of the deposit taken for examaintion.

The coating consists of a soft, very dark brown substance (chocolate color), with the exposed surface of a polished or greasy appearance, much like dark wet mud. This can be readily scraped off, being only loosely attached, and patches had been removed by the flowing water and large portions had slipped down near the bottom. Where the entire area in contact with the water was found coated, the surface was uneven, similar to a "spatter-dash" finish obtained with thin mortar. The surface of new coating resembled a "stippled" finish.

The surface of the concrete beneath the coating had a rough sand finish, due to solution of cement at the surface.

Chlorination Reduced Thickness of Deposit.—The effect if the chlorine had been to reduce the thickness of the deposit, possibly hasten its detachment in areas, and prevent new deposit on fresh cement surface thus uncovered. It was also noticeable that between the old and new water levels no deposit had taken place. This effect of the chlorine reached many miles down the aqueduct since the first new deposit was noted at Newburgh, 37 miles from Ashokan reservoir, and the old coating patches were thicker (¼ in.) than at the point above (⅛ in.) 24 miles. At 48 miles and below, across the Hudson, the entire surface was again coated.

The seven samples were examined microscopically both with and without treatment with dilute hydrochloric acid and there was absolutely no indication of any microscopic plant growth nor organic structure.

All of the above samples were dried in oven at 105 deg. C. The loss on ignition was then determined on these dried samples, measuring water of hydration. During this ignition there was absolutely no odor or organic matter nor any evidence of black char. This would indicate that the deposit was entirely of mineral character.

Qualitative tests of the deposit for the presence of manganese dioxide showed it to be abundantly present. For example, treatment with hydrochloric acid (1:1) produced sufficient chlorine gas to be strongly visible and odorous and heating produced a strong evolution of green chlorine gas, leaving the residue pale pink.

Analysis of Samples.—As there was every indication that the deposits were more or less alike, only samples Nos. 1, 4, 5 and 7 were given detailed analysis, Nos. 1, 4 and 7 being representative of the nearest point to Ashokan, an intermediate point, and the furthest point sampled. No. 5 represented the new growth. In taking these samples it was noticeable that the cement surface had been dissolved by the water, leaving a rough surface of small sand grains. These were obvious also in the samples examined. Under the heading of "Sand and cement from the walls" has been included the insoluble in hydrochloric acid and the soluble silica, lime and magnesia. The last three were very small in amount, ranging from 1½ per cent to 3½ per cent of the total dried weight of deposit. The constituents of the brown deposit have been calculated on a basis of absence of sand and cement from the walls.

The chemical analyses of these samples are as follows (Table I.):

The amount of sand and cement varies inversely with the thickness of the brown deposit due to variation in amount of scraping of the walls in obtaining samples. The deposit from which No. 5 was taken was very thin hence contained much more sand.

Manganese Present in Supply.—It is obvious that the largest constituent of this deposit is manganese dioxide. Determination for manganese in the Catskill water as it leaves Ashokan reservoir showed it to be present at this time to the extent of .04 ppm. It is also present in the Croton supply to the extent of .08 ppm. which is sufficient to cause deposit of manganese dioxide in the bottom of Croton Lake, which is disturbed by the fall over-rising to such an extent that visible brown floc of manganese dioxide is present in the Croton aqueduct water in the fall of the year. This manganese dioxide explains the orthotolidin reaction appear-

Table I

Samples	No. 1 Per Cent	No. 4 Per Cent	No. 5 Per Cent	No. 7 Per Cent
Sand and cement from the walls	35.64	39.98	56.82	37.01
Brown deposit	64.36	60.02	43.18	62.99

Table II—Analysis of Brown Deposit
(Calculated on basis of absence of sand and cement)

Samples	No. 1 Per Cent	No. 4 Per Cent	No. 5 Per Cent	No. 7 Per Cent
Loss on ignition (H_2O)*	25.64	30.25	29.41	27.52
Manganese dioxide (MnO_2)	46.64	41.51	33.09	41.13
Iron oxide (Fe_2O_3)	20.51	24.07	31.73	19.12
Alumina (Al_2O_3)	7.21	4.17	5.77	12.23
	100.00	100.00	100.00	100.00

* No char nor organic odor.

ing before chlorine is added and which regularly increases every fall dropping to almost nothing in winter. Judging from the phenomena observed with the Croton water the small amount of manganese in the Catskill water is probably the source of the manganese deposit on the wall of the Catskill aqueduct.

In the Journal of the American Water Works Association, volume 18, July, 1927, page 1, was described the work of C. A. H. Von Wolzogen Kuhr on Manganese in Water Works in Holland. It is there stated that the deposit of manganese dioxide takes place through the action of certain bacteria and certain mold growths and a special medium is described by which these bacteria were isolated after several months growth. They were obtained from both the water and the brown deposit. This special medium was made up at Mt. Prospect Laboratory and streaked with Catskill water and also from the brown muck. In many tests and after many weeks there was no evidence of any bacterial growth along these streaks causing a brown deposit of manganese dioxide. Certain molds which undoubtedly fell into the plates from the air during examination caused a brown deposit.

Cause of the Deposit.—It is our opinion that the manganese dioxide has been deposited from the water by the effect of absorption of alkali from the cement producing an alkaline reaction adjacent to the wall. This alkaline reaction is necessary for the reaction to take place and the inspection and analyses showed that the cement had disssolved from the surface of the concrete. Iron trioxide and alumina may have similarly been deposited from the water or their source may have been the cement.

It was at first thought that the deposit might be due to bacterial action, inasmuch as it was 1 in. thick prior to chlorination in the aqueduct near Ashokan and covered the entire area of wall exposed, whereas at the time of this inspection the deposit at the first point was in patches and only ½ in. thick and no new growth was noted until sampling point No. 4 was reached. Since there is no evidence of bacterial action and hence sterilizing effect of the chlorine, a possible assumption is that prior to chlorination the alkalinity produced by solution of cement from the surface was greater than at present, thereby producing a stronger alkaline reaction. Also that since chlorination the residual chlorine tends to neutralize any alkalinity produced in the upper portion of the aqueduct and that this action is lost below Newburgh.

The question of addition of chlorine at Newburgh to reduce the deposit below this point and possibly increase the flow of the aqueduct by 30 m.g.d. is still under consideration.

Innovations in Water Treatment

How Some Ontario Problems Were Solved

By A. V. DELAPORTE
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THE removal of turbidity and bacteria has become so standardized, as to require no comment. Taste and color removal without excessive chemical treatment, give an opportunity for novel application of standard methods.

Taste is an elusive thing, and is in part a psychological problem. The delicacy of the perception of taste varies with each individual, and as the flavors of some surface supplies vary with the season, and the temperatures, the investigator is sometimes at a loss to correlate the data which he has collected.

Removal of Phenolic Taste.—The removal of phenolic taste from the Toronto water supply by super-chlorination and dechlorination, is, in the writer's opinion, the greatest innovation in recent years, of water treatment in Ontario. This accomplishment is due principally to Norman J. Howard. The process and results have been fully described by Mr. Howard in the technical press.

In the sanitary engineering division of the Ontario Department of Health, we have approached the same problem in a different manner. We had first to secure a yardstick for the measurement of phenols. We tried several different methods including the Folin & Dennis method, and the Gibbs method. At present we are using the Fox & Guage method with fair results. This method has one major trouble. The indicator is a diazo compound composed of sulphilanic acid and sodium nitrate. This decomposes readily, and must be kept on ice.

The next point of attack on the problem was the source of the taste-producing substance. We found that fresh domestic sewage carried phenol in appreciable quantities. (2) That the phenolic content of sewage increased with storage, phenol being one of the degeneration compounds of the proteins under anaerobic conditions. (3) That phenols were present in wastes from certain industries using coal or its by-products. (4) Water that had been in contact with certain grades of coal tar or oil, carried phenol. (5) That certain wastes from rubber industries carried substances that gave phenol reaction.

Having located a number of possible sources of phenolic pollution, the problem is the prevention of this pollution, and the elimination of the phenol from the water where prevention could not be undertaken.

Here, the advance has not been great. We have proved that phenols are readily oxidized by atomic oxygen. In the activated sludge process—by potasium permanganate, and by chlorination, or in the passage through a properly functioning slow sand filter. To date we have found no practical means of removing phenol by precipitation, absorption, or mechanical filtration, Organic tastes, which after phenol, cause most complaint, are really from three different sources. They are (1) from plankton, (2) from decomposing plankton, (3) from other decomposing organic matter. Some years ago, the writer reported treating the water supply at Richmond Hill with compressed air. It was very evident that a large portion of the taste-producing substances were either gaseous, or of a volatile nature. Continuing our observations at this plant, we found that fairly violent aeration in the mixing chamber caused a foaming. The air passing from the water had a strong marshy smell. The foam, which rose as high as 5 ft., on collection and settling was very similar to a septic effluent in appearance and odor. Chlorine in excess was tried instead of aeration, and gave good results, but not as good as the air had given; but a combination of the two gave really remarkable results.

The water supply of Burks Falls is very interesting. It has color, turbidity, taste, and is slightly acid. The supply is a gravity flow from Reazin Lake through mechanical pressure filters. Reazin Lake, the source of supply, lies in the wilderness about four miles from the town. The filtration plant is about one-half mile out of the town. All chemicals used in the treatment must be introduced under pressure. It was found that pumping a slightly alkaline solution of sodium hypochlorite into the main before filtration, accomplished complete removal of color, taste, turbidity, and acidity. The chlorine oxidized the iron and sulphides, which caused the color and taste. The precipitated iron acted as coagulant on the filters. A clear, colorless, tasteless effluent was obtained.

Color Removal at Dundas.—At Dundas, the problem was color removal without an excessive dose of alum. In order to remove the color successfully using alum only, sufficient alum was required to lower the pH value to the iso-electric point. Acid was used to lower the pH value with minimum dosage of alum without success. Aeration was tried, first in the settling tank, and then in the mixing chamber. The system was arranged after the manner of an activated sludge plant. The floc, as it settled out, was returned to the incoming water, with really excellent results. There were mechanical difficulties in the return of the sludge, which militated against complete success; however, in the remodelling and enlargement of this plant, aeration will be incorporated as a permanent fea-

ture, and the pre-treatment of the water will virtually consist of an activated sludge process.

North York has a periodic disturbance in the taste when there is a heavy run-off from the agricultural land draining into the source of supply. A strong strawlike taste develops. We have controlled this by maintaining a fairly high residual chlorine, and by the use of ferric chloride.

Smith's Falls secure their water from the Rideau Canal. Above the intake, there is a large area of drowned lands which had not been cleared before flooding. This area is a hotbed for the growth of equatic flora and fauna. The result is that the raw water for the town is an aquatic zoo. This summer, the plan is to control the taste temporarily with ferric chloride, and to experiment with aeration in an endeavor to reduce the chemical dosage.

The last experiment was carried out at Brampton last year. Brampton has an auxiliary supply from Snell's Lake. This water, highly charged with micro organisms, is filtered through Ransome drifting sand filters, and chlorinated. Last July, the odor from the filters in the pumphouse became very bad, and there were serious complaints as to taste. Pre-chlorination was resorted to as a temporary expedient. The odors were eliminated, and to a certain extent, the taste also. Even with a dose of 60 p.p.m. of chlorine for three days, we had no residual chlorine after filtration.

Bacteria on Leather Washers

Lactose-Fermenting Organisms Growing on Leather Washers at Chicago

By F. E. GREER and L. C. KELLS
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IN recent years water samples from various hand sampling pumps used to draw waters from the tunnels of the Chicago water supply system have shown unexpectedly high Bact. coli-aerogenes indices which were not explainable on sanitary survey and were not consistent with the current findings of raw Lake Michigan water or with water from other sampling pumps on the same tunnels. The first such instance of persistently high coli-aerogenes indices in a sampling pump occurred at the Lake View station and led to the discovery of an old abandoned sewer near the sampling point on the tunnel. However, after elimination of this possible source of contamination, the high coli-aerogenes findings still continued.

Investigation of Washers.—At a conference of Arthur E. Gorman and H. H. Gerstein of the water control division, with Dr. Fred O. Tonney and the writer representing the research laboratories, it was decided to investigate the washers along the lines reported by Sir Arthur C. Houston in connection with a similar problem arising in the London water works system. The washer was removed by Mr. Gerstein and brought to the laboratory, where it was placed in a mason jar containing 300 c.c. of sterile tap water and kept at room temperature. Examination of the water showed the presence of Bact. aerogenes in large numbers. In the course of a few weeks, the number of organisms had increased to 3,000,000 per c.c. At this point the water in the jar was drawn off and replaced by another 300 c.c. of sterile tap water. An initial drop in the count was again followed by an increase in numbers which soon reached millions per c.c. Repeated changes of water gave the same findings and the washer retained its ability to support growth of Bact. aerogenes for the two years it was under observation in the laboratory.

Following this experience, other investigations led to the discovery under similar circumstances of three examples of washer contamination with organisms of the coli-aerogenes group in the city water supply system. Replacement with new leather washers was in some instances followed by reinfection after a time and recurrence of the same condition. Of the four organisms found growing in the sampling pump washers, one was identified as Bact. coli, one as Bact. aerogenes, and two were classified as members of the coli-aerogenes group by the Standard Methods procedure.

Two leather washers collected from fire hydrants were also found to contain large numbers of coli-aerogenes organisms. Placed in sterile tap water, they developed increasing numbers, one reaching the total of 40,000,000 per c.c. This organism proved to be a typical strain of Bact. coli.

Four other washers from private wells in which high coli-aerogenes findings were not supported by the evidence of the sanitary survey, were found to contain lactose-fermenting organisms of the coli-aerogenes group and to support their continued growth in large numbers for a long period. In all four cases, removal of the infected washers from the pumps was followed by the disappearance of the coli-aerogenes organisms from the well water.

Brass Cylinder Pumps Substituted.—On the basis of this investigation, H. H. Gerstein of the water control division, recommended that all pumps containing leather washers be replaced by brass cylinder pumps. As soon as this was done, the abnormally high indices stopped. There was one exception to this, however, at the Springfield Avenue sampling point. Upon investigation it was discovered that a leak had developed in the new pump and that the engineer had repaired the leak with packing. When the packing was removed the Bact. coli disappeared. In the laboratory this packing yielded many thousands of Bact. coli even after repeated washings.

While these investigations were under way we became interested in the possibility of growing the various lactose-fermenting organisms found in water by experimental inoculation on leather washers.

For this purpose four new leather washers were soaked in alcohol for some time and alcohol gradually diluted with sterile tap water over a period of several days. Sterility tests made on the washers after one week showed no organisms that would grow aerobically or anaerobically on agar plates or in lactose broth.

Experimental Inoculation of Leathers.—Two of the washers were then inoculated with pure strains of Bact. coli and two with pure strains of Bact. aerogenes. The initial inoculum was about 1,000 organisms per washer. The organisms immediately began to increase in number and in a period of two weeks the washers containing Bact. coli showed 6,000,000 and 4,000,000 Bact. coli per c.c. while the washers containing Bact. aerogenes each showed 300,000,000 per c.c.

All of the washers, both those from the pumps and those experimentally inoculated, supported continual growth of the organisms in the jars despite the frequent washings and changes of water.

Another set of washers was inoculated with Bact. typhosus, Bact. aerosporus, Cl. welchii and Strep. fecalis. The tests were carried out as before. There was no increase in the number of these organisms on any of the washers. In the course of a few weeks it was not possible to recover any of the organisms from the water containing the leather washers; moveover, there was no over-growth by other organisms.

The washers which had been inoculated with strains of Bact. typhosus, Strep. fecalis, Bact. aerosporus and Cl. welchii were then immersed in alcohol and the alcohol gradually diluted with water over a period of several days. After they had been found sterile, the washers were inoculated with strains of Bact. aerogenes and Bact. coli isolated from sewage. All the organisms grew luxuriantly, notwithstanding frequent washings and changes of water.

A canvas washer impregnated with paraffin was inoculated with a strain of Bact. cloacae and studied under the same conditions as the leather washers. Bact. cloacae continued to grow for several months. After this time the washer was sterilized and then inoculated with a pure culture of Bact. aerogenes. This organism also multiplied at a rapid rate, notwithstanding frequent washings and additions of sterile water.

At the suggestion of W. F. Langelier of Leland Stanford University in a

letter to Dr. Tonney, reporting a slimy growth which he encountered in well water, we decided to include Bact. mucosus capsulatus in the series. A strain of this organism was therefore inoculated into washers. We obtained a typical slimy growth and the organism increased in numbers on leather washers over a considerable period of time. The possibility of growing coli-aerogenes organisms on leather washers in a continuous stream of water was next tried. The washers containing the organisms were placed in running tap water under conditions of continuous rapid flow, continuous slow flow and intermittent flow. On some of the tests the washers were dried and again tested as in the preceding experiments. In every case the organisms grew readily on the washers in the presence of flowing water. The growing of these organisms in mixtures on leather washers was next investigated. Bact. coli with Bact. mucosus capsulatus and Bact. coli with Bact. aerogenes were tested. All of these organisms grew readily in mixtures on the leather washers. Finally a new sterilized washer was immersed in treated sewage, containing approximately 100 Bact. coli and 50 Bact. aerogenes per c.c. and tested in the manner described. In all these tests the organisms grew and increased in numbers on the leather.

Stream Pollution

Pure Stream Movement Will Accomplish Its Purpose

By SCOTLAND G. HIGHLAND
Secretary and General Manager Clarksburg Water Board, Clarksburg, W. Va.

THE question of pollution of drinking water supply sources is of paramount importance, and we must go into the matter impervious to the pleas of commercialism, and with the determination, should persuasion fail, to carry it by petition to our respective legislatures.

With an increasing population has come an increasing need for good drinking water, and a decreasing available supply; rapidly growing towns and cities spill their filth into sewers that empty into the nearest water channel, while our multiplying industries seek the least expensive method of disposing of their waste. In this matter of steam pollution, however, those directly responsible for it, and we who supinely tolerate it are equally to blame for the crime.

Lack of Vision Basic Cause.—It is astonishing that there should be any opposition to the preservation of clean streams, yet the opposition is strenuous, founded partly on lack of vision, but mostly based upon selfish motives. A misleading argument of the opposition is that the pure stream movement is backed by sportsmen, and that it is an impractical dream; that the people are confronted by a choice between fish and industry. This contention is absurd, for not only fishermen, but all intelligent persons recognize the fact that the water of streams in which fish cannot live is unfit for human beings to drink, and that the preservation of human life is necessary for the continuance of industry.

Defilement of Streams Indictable Offense.—There is a great deal of ignorance among industrial heads about the legal status of stream pollution. There seems to exist a prevailing impression that the pollution of lakes and rivers is a perfectly natural, and even lawful custom in the absence of specific statutes prohibiting it. The contrary is true. Polluters, great or small, are law breakers. Many highly respectable offenders do not know that from the early days of common law, the defilement of streams has been an indictable offense when such defilement affects the public, and the right to restrain by injunction any one who corrupts water with industrial waste is a very ancient right.

Education is the Solution.—A better remedy, however, lies in the arousing and educating of our people to the gravity of the situation, and a special effort should be made to induce manufacturers and those connected with polluting industries, to give their personal thought and time to the investigation of present conditions. They are keen, level-headed men, and they do not take delight in poisoning the water needed by the people; in this age of terrific efficiency they have sought to keep down the expenses of operation by getting rid of the waste in the most convenient manner, with little if any thought about the result.

In years gone by, there was little complaint; our streams were numerous and full of water, our industries comparatively few, our population small, and under those conditions the water, most universal of solvents, could digest or carry away impurities. Our streams can no longer do this, and if the industries do not realize this fact it is certainly time that they were told it.

Many of those who are engaged in industries that pollute water are citizens of the finest type, as proud of their community, state and country, as the rest of us, but much missionary work must be done among them, where one convert will count as many missionaries.

Industrial Chemists Problem.—Practically every business involves problems that must be solved in office or laboratory. It is not the duty of the water utilities nor of the state to conduct experiments for the solving of the waste disposal problem for the hundreds of industries within its bounds. The cost of maintaining a corps of skilled chemists would be prohibitive, but every plant, or particular industry is forced to employ the best engineers and chemists in its special field. These experts are best fitted to deal with and solve this problem, and a definite co-operation of one with all, would reduce the cost of experimentation to a minimum sum, which, when apportioned would not bear too heavily upon any one of the numerous enterprises affected. It is but just that the expense of experimenting should be borne by those who are making money in the offending industries.

Using Water Courses as Sewers.—The only duty devolving upon the state is that of telling big and little business, individuals, communities, hamlets, villages, towns and cities that they can no longer use the streams as sewers, and that they must take prompt action in otherwise disposing of their waste product. Experience thus far shows that, unless forced by law or a supervising state agency, industries will not change their present life-destroying methods, but although the task of converting the manufacturers and other polluting groups may be difficult, compensation is to be found in the rapid progress now being made in educating the rest of the community to vigorous and incessant protest that will result in legislative action in the matter.

Accept the Inevitable.—The pure stream movement is based upon the primal law of "the inalienable rights of the people"; it will accomplish its purpose, and unless the polluters accept the inevitable, take the initiative and show the people a commendable willingness to clean house, an indignant public may demand legislation of so drastic a nature that real industrial harm would ensue.

Far Afield for Drinking Water.—Many cities have had to go far afield for their supplies, as the capacity of wells, adjacent stream or lake, became inadequate to meet the demands of the community, but very often it was the pollution of the local supply that made necessary the seeking of more distant sources.

Far Afield for Drinking Water.—Conspicuous examples of such cities are: Los Angeles, which brought her new supply from 235 miles away; San Francisco, 154 miles; New York, 120 miles; Tulsa, Oklahoma, 60 miles; Phoenix, Arizona, 32 miles; Butte, Montana, 27 miles; Denver, 25 miles, and Norfolk and Portsmouth, Virginia, about 20 miles each.

Winnipeg, Canada, brought her new supply a total distance of 98 miles, while Victoria went 38 miles for water.

In Australia the Coolgardie pipe line is 351 miles in length, and in southern Italy, the Apulian Aqueduct, constructed in 1924, to supply 266 communities, comprises 152 miles of main conduit, and 841 miles of main and subsidiary branches leading therefrom.

Self-Preservation the Issue.—In view of the enormous expense incurred by carrying water such distances, an expense which the people at large must bear, it seems incredible that they have ever tolerated the corruption of nearer

supplies of something essential to the preservation of their lives.

Experience is not only a hard, but a very costly teacher, but the growing agitation over the pure stream question, will be the means of protecting the fledgling cities of today, and those of future years from the gross wrongs inflicted on us by the pollution of drinking water supplies.

Water Borne Treponema Pallidum.—Investigations carried on behind the battle lines in Europe have modified, to a considerable degree, the opinion prevailing among physicians and sanitarians that no danger existed from the bodily discharges of persons infected with the deadly germ treponema pallidum. The danger is now quite generally recognized, and the fact that these germs will survive for a long time in sterilized water was announced by the eminent Dr. Roseneau as early as 1916. Water pollutes itself from what is washed.

Colloids in Water

Effect on Turbidity and Color

By C. H. CHRISTMAN

Filtration Department, National Aluminate Corp., Chicago

WE are all more or less familiar with turbid waters which will not settle completely on long standing. The existence of coloring matter in colloidal condition has also been noted. Careful filtration of a raw water fails to remove some of this turbidity and color, and it is with this material that our interest centers at present. We are familiar with the fact that some waters can be efficiently coagulated with a minimum of chemical while others require many times this amount to secure the desired results. In some instances this condition may be due to the nature of the dissolved material, yet in others there seems to be a relationship between the nature of the suspended matter and coagulating dose. Some waters require very careful regulation of pH to secure good coagulation and in other instances this control appears to be unnecessary. In addition to matter which finds its way into water naturally, pollution from domestic and industrial sources add to the colloidal content of water.

It may be stated definitely that the presence of a colloidal condition in raw water does not mean that matter, so present, is organic or inorganic, from natural sources on a water-shed or from pollution. It may be from any or all of these sources. A colloidal condition indicates that matter of some type is present, not in true solution, yet in a state of sub-division in which the particles are separate entities, though submicroscopic in size. In fact, we believe that matter of vegetable and inorganic origin may occur in colloidal condition. With colloids resulting from pollution as well, it follows that each type will present a problem in itself when we consider the removal of the colloid by coagulation.

Differentation of Colloids. — Our knowledge of colloids and their characteristics indicates that some are acid, some neutral and some alkaline in character. Their reaction in an electrical field may be used to differentiate them into charged and uncharged colloids. It does not indicate whether they are of organic or inorganic origin. For this study, it is necessary to concentrate them by ultra-filtration through a suitable membrane and study them further. By connecting a battery or other source of direct current to electodes in a U-tube which contains a colloidal water, migration of the colloid occurs and coagulation may be observed at the electrodes. A critical study of this particular phenomenon should lead to the development of fundamental data which might be of importance in answering some of the problems relating to coagulation.

The present report must be considered as preliminary, in that phases of the study have not been completed. It is presented, however, with the hope that it will arouse the interest of others, precipitate thought and discussion, toward the end that our common knowledge of colloids in water supplies may be increased.

We have been concerned in particular with the occurrence of colloids in water, their prevalence, the nature of any charge they carry, their migration in an electrical field, the neutralization of the electric charge carried and its effect upon the existence of the colloidal state, the extent of the charge carried, any relation between colloids and pH, the existence of an iso-electric point or optimum pH at which they can be coagulated, together with such supplementary data as might be gleaned in the course of a study such as this.

Use of Ultramicroscope.—For this investigation, use has been made of an ultramicroscope. The cataphoresis cell contains the sample under investigation. It is provided with stopcocks for filling and draining. A capillary tube with a 1 mm. opening connects the two reservoirs, in which the platinum electrodes are sealed. The distance between the electrodes is 15 cm. The electrodes are connected to radio B batteries to assure sufficient voltage for migration rate studies. pH values were determined by colorimetric methods.

In using the ultramicroscope, water is placed in the cell with the level above the top stopcock. This is closed to prevent movement of the water during observation. A very strong beam of light is directed through condensing lens and upon the water perpendicular to the axis of observation. In this manner it is possible to observe the manifestation of a colloidal condition. The rays of light passing through the water strike a colloidal particle and are diffracted. This condition may be observed, for it is similar in character to the effect of a beam of sunlight in a dusty room. The individual particles, otherwise unseen, become apparent when light is reflected from their surfaces. Finding this condition in a raw water, we proceed to estimate the extent of the colloidal condition. This has been empirical thus far, but in future work it is planned to combine dialisis studies with the ultramicroscopic examination so that quantitative data may be available. Next, the cell is connected to the batteries and observation made to note migration of colloidal particles. If migration is observed, the direction of current flow is reversed to ensure that migration is due to the current rather than to movement of particles with water flow. In this manner we have observed particles flowing with the negative current toward the positive electrode.

Charged Colloidal Particles and Coagulation Requirements.—It has been our belief that colloidal particles which are charged might carry more or less of the electrical charge and this condition might be correlated to the coagulation requirements of the water. If the particles vary in the amount of their charge, attraction to an electrode under a constant current flow should vary and their rate of migration should be proportional to the charge carried. Ellms reports the measurements of colloids in Ohio River water as 0.29 centimeters per hour with a potential gradient of 4 volts per centimeter. The ocular of the microscope used in this work is fitted with a graduated scale. Movement of the colloids across this scale were observed and the time required for the movement across a measured distance was checked by a stop-watch. Observations were repeated and average values were obtained. It is worth noting that most of the samples showed little variation in the rate of migration, while some few gave wide variations. In this manner data were secured which rate the samples in terms of migration per centimeter per second per volt.

The samples were raw waters which were received in our laboratory for analysis. Coming from all sections, a wide variation in samples might be expected. The possible relation of other analytical data to the colloidal condition will be studied further and will be presented in a future report.

Colloidal Particles Charged with Electricity.—We have found that the colloidal particles in the raw waters studied are charged with electricity, the charge is negative in character, the rate of migration of colloidal particles induced by direct current varies and this variation is a function of the amount of charge carried. There seems to be no generic relation between the rate of migration and pH of the raw water.

Dispersion of colloids results from the similarity of charges which the particles carry. Neutralization of these

charges, by any methods, will remove the condition which prevents the coagulation of these colloids. The effect of the electric current has been demonstrated and is being tried on a plant scale at one of the larger plants in the west. The coagulants used in general practice give a colloidal condition under certain conditions and it is known that these colloids are positively charged. Thus, when colloids of opposite charge are mixed, there is mutual neutralization and precipitation. The effects of various colloids and the different coagulants are being investigated. It is possible that this will lead to the use of specific treatment for certain water conditions, giving better operation, greater control and improved water.

Water Treatment for Industrial Use

Recent Developments in Boiler Operation and Their Influence on Feedwater Treatment

By SHEPPARD T. POWELL
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LOCAL conditions have a marked influence upon feed water problems everywhere, yet fundamental knowledge on the subject of water conditioning is the foundation upon which the solution of the problem ultimately must rest. This conception of water treatment for industrial use now seems to be quite general among American engineers responsible for the safe and economic operation of steam generating equipment. Much time and effort has been expended in attempting to establish and carry forward broad fundamental research. As a result of such effort, at least two important investigations have been tentatively arranged. These are study of the mechanism of priming and foaming of water under steam conditions and the determination of the hydrogen ion concentration of concentrated boiler water under steam conditions. The necessity for such research is clearly apparent and the result of these studies should do much to improve our knowledge of two of the most perplexing problems in steam boiler operations, i. e., wet steam and corrosion of boilers and appurtenances.

It is difficult to justify a specific list of new appliances or processes in this or other fields without creating useless controversial discussion. We shall not attempt therefore, to do more than direct attention in a general way to indicated trend of developments.

The Most Recent Development.—Possibly the most interesting recent engineering development in feed water treatment has been the combination of various forms of water purification processes. The combination of chemical and zeolite softening, additions of coagulants with softening reagents, continuous blow-down system and steam purifiers has revolutioned feed water treatment. This has made possible a broader field for the designing engineer than previously was considered possible.

The conditioning of feed water is no longer limited to a single process but a series of corrective treatments. The arrangement and extensiveness of the design will depend upon the steam station requirements and economy resulting from the combination treatment. Recirculation of concentrated boiler waters has been used in the past but has not been widely employed. Recently a number of novel applications have been made which are attracting attention since they have some merit for specific conditions. In some of the designs recirculating only with heat recovery is effected while in others partial softening also takes place.

Increased Use of Softening Reagents.—No new chemicals of importance have been produced for water conditioning but there has been a very marked increase in the use of some softening reagents. This is particularly so in the case of phosphates and sodium aluminate. The increased use of the reagents is due primarily to purer products and more exact knowledge of their value for specific conditions. The investigations to determine methods of water treatments to inhibit embrittlement of boiler steel have been partially responsible for the increased use of phosphate. Both di and tri sodium phosphate have been used in the past. Mono phosphate has been now offered for this service. This product has some advantage over the other sodium salts since the desired soluble phosphate is obtained with a lesser concentration of the sodium radicle.

Electrolyte Methods.—Inhibition of corrosion of boilers, heaters and condensers by electrolytic methods has continued to attract attention and a number of successful installations have been made during the past few months. Research work has been conducted at at least two universities in an effort to determine the cause of this phenomenon. A number of theories have been advanced to account for this form of protection but experimental data is lacking which would account for the mechanism involved in the retardation of the corrosion rate.

A number of valuable contributions to the art of industrial water treatment have been made recently. Possibly the most constructive study in reference to the mechanism of scale formation has been the work of Dr. E. P. Partridge, conducted at the University of Michigan. The data presented by this investigator have thrown new light on deposition of scale forming solids and should prove of value in directing attention to future methods for controlling scale formation in evaporators and in boilers. Similar work is to be carried on by others along the same general line as pointed out by Dr. Partridge. The results of this work will be awaited with interest, since it may lead to revolutionary ideas in reference to the fundamental idea of scale growth.

The recent corrosion study by Dr. R. U. Evans has added much to our knowledge of film formation and the inhibition of corrosion by this action. Although this work is not a specific study in boiler water treatment, the scientific facts established have great application to the control of corrosion problems encountered in steam generation.

A number of very valuable contributions relating to embrittlement of boiler steel have been made through the Verein Deutscher Ingenieure. Likewise, the work of *Thiel and Luckman on the same subject will be found instructive in reference to German investigators' viewpoint on this important problem.

Many New Problems Encountered.—Many new problems have been encountered, which may not be solved without more intimate knowledge of the chemistry of water. The presence of non-condensible gases in steam, especially carbon dioxide, has given much concern to those responsible for steam station control. Acid steam from this source is much more frequent than is usually suspected. No solution for the control of the difficulty is at present available. The disassociation of even pure water in steel economizers, and superheaters has been shown recently to be a potential possibility under certain conditions. The detrimental effect on steel, from such disassociation products, is well known and must be avoided since the resulting damage is permanent and may be very costly. The problem may not be discussed intelligently since much study must be given to it over a wide range of conditions before the extent and acceleration of this destructive action on steel can be determined accurately. The report on this subject by Mr. C. H. Fellows to be presented at this meeting shows the potential possibilities of the disassociation of water. One industrial concern is now conducting similar experiments at pressures up to 4,000 lb.

The aim of this group to solve these numerous problems by cooperative effort has been recognized as a constructive program, to accomplish the desired results with the least duplication of effort. The influence of this movement has attracted attention from similar European groups and tentative plans have been arranged to have exchange of ideas with at least one of these cooperative research associations. International exchange of ideas leading toward the solution of these problems should be mutually beneficial.

There must necessarily be more or

*Committee report on feed water studies of the Association of Large Boiler Manufacturers.

less lost motion in carrying forward any cooperative work of this kind. There are so many specific problems that are peculiarly important to each group that it is not possible to confine the work of these committees to any specified plant control measures. The most that can result from the effort of this work is to establish fundamental concepts and to arrange these data for practical use. With a clear understanding of the problem based upon established facts as to the cause or causes of the specific phenomena, corrective treatment is fairy well assured.

Selecting Pumping Equipment

Some of the Broad General Principles

By A. P. PIGMAN
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THE engineer in selecting equipment for a pumping station may be confronted by an almost infinite variety of situations. Any fixed rule drawn from the solution of one problem is almost sure to be misleading in the solution of the next. Yet, in order to shorten his task and to make it more more nearly certain that the solution of each problem will be very close to the best solution possible, it is desirable that we discover, if we can, some broad general principles for his guidance.

Situations to Be Met.—In classifying situations to be met, we have to consider a great variety of things, such as the purpose of the installation—whether a new plant is to be built, or additional capacity added to an old plant, or more efficient equipment added to an inefficient plant. We have to consider the character of the service—whether it is to be single pumpage, double pumpage, or a combination of single pumpage with a ground water supply. The load may be uniform and vary only seasonably, or there may be wide daily fluctuations, superimposed upon seasonal fluctuations, and even the head may vary, especially when fire pressure must be raised. Finally, water works plants may vary in the quantity of water pumped and the head pumped against all the way from small stations requiring only 2 to 3 horsepower to large stations requiring thousands of horsepower. The variety of circumstances is almost without limit.

Table I

		Bhp.
Group 1		
	Average Load	above 1200
	Typical Plant av. load	1600
	Typical Plant max. load	2000
Group 2		
	Average Load	600-1200
	Typical Plant av. load	800
	Typical Plant max. load	1000
Group 3		
	Average Load	250- 600
	Typical Plant av. load	400
	Typical Plant max. load	500
Group 4		
	Average Load	below 250
	Typical Plant av. load	160
	Typical Plant max. load	200

Table II

		Steam	Diesel	Electric
Group 1	Fixed Charges	41,400	40,500	11,000
Av. Load	Labor	21,600	14,400	10,800
1600 Bhp.	Fuel or Energy	26,000	60,000	112,000
		89,000	114,900	133,800
Group 2	Fixed Charges	27,800	22,500	7,000
Av. Load	Labor	17,000	10,200	8,500
800 Bhp.	Fuel or Energy	16,200	30,000	56,000
		61,000	62,700	71,500
Group 3	Fixed Charges	20,200	12,900	3,400
Av. Load	Labor	14,400	8,000	6,400
400 Bhp.	Fuel or Energy	10,000	15,000	28,000
		44,600	35,900	37,800
Group 4	Fixed Charges	12,000	6,000	1,500
Av. Load	Labor	10,500	6,000	4,500
160 Bhp.	Fuel or Energy	5,000	8,000	11,600
		27,500	20,000	17,600

Classification of Types of Equipment.—To meet these situations, there are many types of pumping equipment, but at least one simple classification of these can be made based on the source of energy used for driving the pumps. Practically all pumping plants are operated either (1) by steam generated at the plant, or (2) by internal combustion engines, or (3) by electric energy purchased from the local power company.

Using a size classification based on the horsepower required to operate a plant, I have taken four typical plants and have made a comparison of the annual cost, including fixed charges on investment, of operating each of these four typical plants, first, with steam equipment, then with Diesel power and, finally, with purchased energy. Four series of studies are made of these four sizes of plants each using the 3 types of drive, steam, Diesel, and electric.

In the first series of studies it is assumed that the water is pumped only once; that is to say, the plant pumps either all raw water or all clear water. It is further assumed that there is a large reservoir in the system, so that the load is uniform, varying only seasonally. Finally, it is assumed that the problem is to build an entirely new plant. The 3 types of pumping equipment are fitted into this situation for each of the four sizes.

After this first series of studies, a study is made of the effect of double pumpage being substituted for single pumpage. Then the effect of a fluctuating load is investigated and, finally, the problem is reviewed in the light of merely adding new capacity to an existing plant rather than building an entirely new one.

Pumping stations have been divided, more or less arbitrarily, into four groups (see Table I) based on the brake horsepower required to carry the average load. For each group, a plant requiring an average horsepower somewhere near the middle of the group is taken as typical.

As a working basis in all of these studies, the cost of coal is taken to be $3.00 per ton, the cost of Diesel engine oil 6 ct. per gallon, and the cost of electric energy including demand charges, 1 ct. per K.W.H.

Summary of Four Typical Cases.—1. When a new plant is to be built for single pumpage at a nearly uniform rate a steam plant will usually be the most economical provided the load is sufficient to call for turbines of more than 1,500 horsepower capacity. (See Table II.)

2. For similar plants with loads averaging less than 250 horsepower the electric plant will ordinarily be most economical but, if the power rates are high, the Diesel plant will be better.

3. In between these the field is highly competitive for the three types of equipment with the Diesel having ordinarily a slight advantage which tends to give way to the steam plant in the upper ranges and to the electric plant in the lower ranges.

We next consider the effect of pumping the water twice instead of once in each of the four cases. It is assumed that first raw water is pumped against a head of 50 ft. and that clear filtered water is pumped against the remaining 250 ft. It is suggested that for each of the three types of equipment the low service pumps and pit will cost approximately the same for in the case of the steam plant or the Diesel engine plant the most economical arrangement is to have small centrifugal low service pumps driven either by water turbines or electric motors, taking the energy either from water pumped by the main high service unit or from a generator driven by that unit. The added cost for the extra equipment in the case of the steam and Diesel plants beyond what would be added for the electric plant will be small amounting to about the following:

	Investment	Fixed Charges
Group 1	$15,000	$2,250
Group 2	10,000	1,500
Group 3	6,000	900

Obviously this is not enough to appreciably affect the relative standing of the three types of equipment in the three cases.

Fluctuating Load.—If the plant to be built is to have a fluctuating load instead of merely seasonal variations, the effect on the results obtained in the first series of studies is considerably more marked. The three series of studies considers this situation and assumes that the load fluctuates sufficiently for

Table III

		Uniform Load	Fluctuating Load	New Unit Added to Old Plant
Group 1	Steam	89,000		
Av. Load	Diesel	114,900		
1600 Bhp.	Electric	133,800		
Group 2	Steam	61,000	71,500	47,100
Av. Load	Diesel	62,700	70,200	55,600
800 Bhp.	Electric	71,500	79,800	70,600
Group 3	Steam	44,600	52,600	33,400
Av. Load	Diesel	35,900	40,200	34,200
400 Bhp.	Electric	37,800	39,700	37,800
Group 4	Steam	27,500		20,900
Av. Load	Diesel	20,000		17,900
160 Bhp.	Electric	17,600		17,200

the maximum load to be twice the average. The effect is shown in the second column of Table III.

The average load has remained the same, hence fuel and labor costs have remained the same. This may not be strictly true because due to the greater fluctuation in load equipment cannot be kept operating at all times in the regions of best efficiency, but, if the nature of the load has been carefully studied before hand and the equipment carefully selected, there need not be very much loss.

The peak load being 60 per cent higher, 60 per cent more equipment and hence 60 per cent more investment is needed. This influences adversely the steam and Diesel plants where fixed charges represent the largest portion of the total. Thus we find that steam and Diesel plants have lost some of their advantage in the two larger groups and that the electric plant takes first place in the third group and increases its lead in the fourth group.

Adding Equipment to an Existing Plant.—The fourth and last series of studies assumes that instead of building a new plant the problem is to add more capacity to an existing plant. (See Table III.)

Here the effect on the original four studies (see column 3 of Table III) is exactly the reverse of the effect of a fluctuating load. Again the fuel cost has remained unchanged but since no duplication of equipment has to be provided for, the amount of equipment needed is less and hence the plants which require large unit investments are benefited. We find now that in group 2 the steam plant has gained a considerable advantage and even in group 3 it now shows the lowest annual cost. Even in group 4 the cost of Diesel oil need only go to 8 ct. and of electricity to 1 1/3 per KWH. for the steam plant to show up as well as the other two.

If the added capacity is for meeting peaks only the Diesel or electric plant may regain their advantage over the steam plant.

Even if new capacity is to be used for regular service the steam plant should not be given the full advantage indicated by the third column of Table III if the existing equipment which will serve as standby is old and in bad shape and will have to be discarded in a few years.

There are many small plants smaller than the typical plant of group 4 pumping a million gallons per day or less where for the sake of convenience alone an electric plant may be justified even at a slightly higher cost since the amount involved cannot be great.

Reciprocating Pumps.—In all four studies the steam plant has been worked up on the basis of turbine drive. In the two large groups a reciprocating pump is practically out of the question but in the two smaller groups there will be occasions where the highly efficient crank and fly-wheel pump will make as good a showing as turbine driven units. Since, however, in the building of new plants a steam plant can generally be justified only in the larger sizes, this means that the installation of new reciprocating pumps is practically limited to a portion of the cases where steam equipment of any kind can be justified in making additions to existing plants. It is pointed out, however, that, where these highly efficient crank and fly-wheel pumps are in good operating condition and additional pumping capacity is not needed, there is no possibility of installing any other type of equipment for the purpose of reducing operating expenses.

General Summary.—We have passed in review a large variety of situations to be met in the installation of new pumping equipment. We have attempted to classify these situations and to show that under one set of circumstances one type of equipment generally had an advantage and in another set of circumstances another type generally had the advantage. Hardly anywhere, however, have we found that any type of equipment has an undisputed field. Even in the cases where one type of equipment seemed to have the greatest advantage over the others, our analysis showed that a change from what might be considered an average in the cost of coal, of oil or of electric energy, would make another type more suitable.

In general we found that for a new plant having a uniform pumpage rate a steam plant generally had quite an advantage, provided the plant was large enough to justify the installation of a turbine of more than 1,500 horsepower. On the other hand, if the horsepower required were less than 250 or 300 the electric plant generally had an advantage. In between these sizes the Diesel plant had a slight advantage but was closely competitive with steam as the sizes approached the upper limit and with electricity as the sizes approached the lower limit.

We found further that whether the pumpage was single or double pumpage made very little difference.

We next found that if the load had wide fluctuations more equipment was required to handle the same average load and, therefore, the low unit investment of the electric plant was given a greater advantage than it possessed in the case of the uniform load and its field accordingly expanded.

On the other hand we found that if instead of building a new plant the problem were to add capacity to an existing plant the amount of equipment required to take care of a given load would be less and the steam and Diesel plants with their low operating costs would be given a greater advantage than they possessed where a new plant was to be built and the field of these plants was, therefore, expanded down into smaller sizes than otherwise.

Ground Water in Yellowstone and Treasure Counties, Mont.

The Department of the Interior announces a report entitled "Ground Water in Yellowstone and Treasure Counties, Montana," by George M. Hall and C. S. Howard, just issued. The report, which is listed as Water-Supply Paper 599 of the Geographical Survey, was prepared in cooperation with the state engineer of Montana, the department of chemistry of the Montana State College and the water laboratory of the Montana State Board of Health. It may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 25 cents a copy.

These two counties are traversed by the Yellowstone River, and on the lowlands near the river wells generally yield large quantities of water, although much of it is of poor quality. On the upland in many places the inhabitants have difficulty in finding adequate supplies of good water even for domestic use. A careful study of the geology has shown that in some places where the surface conditions appear to be unfavorable or where the water is of poor quality, good supplies may be obtained by drilling to deeper formations. The Geographical Survey report gives not only general descriptions of the rock formations but also more detailed discussions of the conditions governing the occurrence of ground water in each of the more than 100 townships that lie in the two counties.

The report contains data in regard to 100 wells, with analyses of water from them and other information in regard to the quality of the water. It also contains a geologic map showing the distribution of the rock formations, cross-sections showing the geologic structure and notes in regard to the unusual natural features of the region.

Activated Sludge Plant Operation in Great Britain

Experiments at Reading, England, Discussed in Paper Before Royal Sanitary Institute

By A. S. M. PARSONS
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A GENERAL idea seems to have prevailed that the process is a simple biological one wherein a specific micro-organism oxidizes the impurities of sewage, and Dr. Calvert has cited the vinegar process as analogous to the popularly accepted theory. In this process, it will be remembered that a specific bacterium does in aerobic conditions actually oxidize alcohol to acetic acid.

In attempting to deal with some of the difficulties encountered in the activated sludge plant which has been installed for the Reading Corporation, the writer was forced to the conclusion that many of the empirical rules and ideas commonly adopted in the operation of such plants are not really generally applicable, and that the process cannot properly be described as simply biological.

The Velocity of Reaction.—In commencing the study of a reaction by physical chemistry methods, one of the first steps is, usually, to consider the velocity. The recation that is, of course, under investigation in the activated sludge process is the removal of the impurities in the sewage, and the results obtained can be most conveniently studied if plotted as a curve, the slope of which will indicate the rate of removal of the impurity, i. e., the velocity of reaction.

Since in their paper (Society of Chemical Industry, Jan. 3, 1927) Messrs. Butler and Coste referred to this instantaneous effect and considered it was appreciable, we endeavored to devise a critical experiment in order to show whether or not this was the case. The experiment was as follows:

Sewage was allowed to settle overnight and the supernatant liquid only used.

Into three 500 c. c. cylinders were placed:

1st cylinder—150 c. c. sludge (settled for one hour).

2nd cylinder—150 c. c. effluent from which the sludge had been settled.

3rd cylinder—150 c. c. distilled water.

Sufficient carefully mixed settled sewage was added to each to bring the total volume to 500 c. c., and the mixtures in the cylinders therefore consisted of 70 per cent sewage with (1) 30 per cent sludge; (2) 30 per cent effluent; (3) 30 per cent distilled water. The cylinders were each turned over twice thoroughly to mix the contents, allowed to stand for one hour, the supernatant liquids poured off and examined, with the following results:

Experiment T29

*Oxygen absorbed in three minutes; parts per 100,000

	1	2	3
	30 per cent sludge	30 per cent effluent	30 per cent distilled water
Results found	1.42	1.56	1.46
Results calculated	1.60	1.60	1.47
Difference—			
Instantaneous effect	0.18	0.04	0.01

The sludge for the experiment was in excellent condition for clarification, and it is to be noted that the liquids were not filtered, but were settled for one hour. There was a small amount of fine suspended matter (sludge particles) in the effluent used in No. 2.

The "instantaneous effect" is seen to be slight, and we venture to suggest that the results obtained by Messrs. Butler and Coste were due to the fact that their mixtures were filtered. The experiment does, however, show that even if sludge is allowed to fall but once through sewage, there is some removal of impurity as could very well be predicted from our knowledge of adsorption effects or of the action of enzymes.

The next point which must strike the observer is the enormous rate at which the three minutes oxygen absorption figure drops.

First Action in Process.—Examination of the effluent reveals that clarification has been achieved by the time the oxygen absorption curve flattens out to an approximately horizontal line, and it has been asserted on many occasions that the first action which normally occurs in the activated sludge process is clarification or the removal of colloids. Whilst objections have been advanced against this opinion, the following considerations seem to us conclusive:

1. The process may be interrupted at the point when clarification is achieved, and before little or any nitrates or nitrites are found.

2. Only an abnormal sludge, prepared usually by very prolonged aeration without sewage will nitrify first, but such a sludge will fail to clarify.

3. A sludge which will clarify well, but will not nitrify can be produced in two or three weeks, whilst the preparation of a nitrifying sludge requires a much longer time.

4. The Birmingham flocculated sludge process is a large scale demonstration that clarification is a distinct process, and is the first stage of the activated sludge process.

Three Distinct Stages.—That there are distinct reactions or "sections" in the process was recognized by Ardern and Lockett in their original paper (Society of Chemical Industry, May 30, 1914), but neither of these workers nor others seem to have pursued their studies very far in this direction.

Consideration of these and many other points has led the author to the conclusion that in the activated sludge process at least three distinct stages must be recognized:

1st stage—Clarification.

2nd stage—Reactivation or restoration of the powers of clarification.

3rd stage—Nitrification.

Stages 2 and 3 may go on simultaneously, and whilst stage 2 is absolutely necessary for the maintenance of stage 1, stage 3 is not necessary.

Granted the correctness of the foregoing deductions, the writer ventures to submit the following notes upon the first or clarification stage.

The Clarification Stage.—The term "Clarification" must be understood to signify not only the removal of colloidal matter, but also removal of some substances from true solution, as well as, of course, any matter in actual suspension, This use of the term is, of course, similar to its use in describing the clarification test modified by Fowler and Ardern for the approximate estimation of colloidal matter in sewage.

It has been said that the clarification of sewage when it is agitated with activated sludge may be due to:

1. A scrubbing effect.

2. Combustion or combination of the impurities with oxygen.

3. Induced combustion brought about by catalytic action of the activated sludge.

4. Biological action, including (a) carbonaceous fermentation, (b) proteolysis, (c) direct cell action.

5. Physical action, such as absorption of the impurities in or upon the sludge.

6. Combinations of some of these actions.

Let us deal with these statements in turn.

Scrubbing.—It is difficult to understand what is meant by "scrubbing" in this connection. One supposes it may

*The three minutes oxygen absorption figures for settled sewage and effluent were 2.10 and 0.42 respectively, and the calculated results in the above table are arrived at from these figures.

be intended to convey the idea of more or less violent interfacial contact. Quite how this could affect purification is not clear, but in any case the writers have never seen any arguments adduced that carry the suggestion very much further.

Combustion: Induced Combustion.—If clarification really is combustion either with or without the aid of catalysts (and enzymes are catalysts) then it follows that oxygen is necessary for the combustion. This being so, oxygen must be obtained either from solution (that is, from the atmosphere or applied air) or alternatively is stored up in the sludge during reactivation.

This point can be studied experimentally, but while it is a simple matter to investigate the reaction when atmospheric oxygen is excluded, it is not so easy to eliminate all oxygen or oxidizing agents from the sludge while retaining its active character. On the other hand, examination of the sludge does not reveal any large store of free oxygen, the presence of nitrates or nitrites being immaterial since clarification can quite well (or perhaps even better) be performed by a sludge which is incapable of oxidizing ammonia.

Clearly if clarification is a combustion process, it could not occur to any appreciable extent in the absence of aeration, and the following experiment was undertaken to prove that aeration is not essential:

Experiment to Prove that Aeration is Not Essential.—Sewage was used which had been settled overnight to remove all but the finer suspended matters. The activated sludge used was in good condition, and had been thickened by settlement for one hour.

To separate quantities of the settled sewage sufficient sludge was added to give the proportions stated below.

Series A was performed in bottles two-thirds full only, and the stoppers were removed from time to time to slightly renew the air.

Series B was performed in completely filled and well-stoppered bottles; no air being admitted.

The bottles were all shaken by hand for one hour, the aim being to keep the sludge from settling and on the move all the time.

At the end of the one hour of agitation all were settled one hour, the supernatant liquids were decanted off, and the effluents examined.

Oxygen Absorbed in Three Minutes, Parts per 100,000 Settled Sewage 1.78

	A (aerated)	B (not aerated)
5 per cent sludge	1.40	1.58
10 per cent sludge	1.34	1.38
15 per cent sludge	1.14	1.32
20 per cent sludge	1.04	1.20
25 per cent sludge	0.94	1.28

The experiment shows that whilst air assisted and improved the action, the clarification stage can go on in the absence of aeration.

Experiment No. T.49.—Experiment T.49 is a variation of the above, but in this experiment, whilst series A was agitated in 500 c. c. cylinders by means of compressed air from an open glass tube, series B was agitated by gently inverting, shaking, and swirling in stoppered bottles. In this case, instead of different amounts of sludge, the sewage was diluted to different extents by means of distilled water.

Sewage settled overnight was used, and the mixtures were agitated or shaken for half an hour, then settled for one hour.

Three Minutes Oxygen Absorption, Parts per 100,000*

	Calculated figures for mixture excluding clarification	Observed figures Series A (Aerated)	Series B (Not aerated)
Settled sewage, plus 10 per cent sludge	1.75	1.44	1.48
67.5 per cent settled sewage, plus 22.5 per cent water, plus 1 per cent sludge	1.33	0.98	1.08
45.0 per cent settled sewage, plus 45.0 per cent water, plus 10 per cent sludge	0.90	0.62	0.70
22.5 per cent settled sewage plus 67.5 per cent water, plus 10 per cent sludge	0.48	0.38	0 42

Again it is shown that clarification takes place in the absence of air, but is improved by its addition.

The experiments just quoted do not, of course, rule out the possibility that there may be a store of some oxidizing agent in the sludge itself, but the fact that nitrates or nitrites need not be present while clarification is taking place almost eliminates them from the problem. If there is an oxidizing agent present in the sludge it has not been identified. There is not, however, any evidence (so far as the writer is aware) that any really extensive amount of oxidation does not take place at this stage.

Buswell, in experiments on the relative importance of oxygen and stirring, concluded that stirring is more important (in the clarification stage) than oxygen, and that activated sludge will function at oxygen levels so low that they can scarcely be measured.

It may be accepted then that although aeration during clarification may help, it is not essential to this stage.

Carbonaceous Fermentation.—This term has been much used and signifies the conversion by bacterial agencies of complex carbon compounds into simpler carbon compounds with evolution of carbon dioxide or other gas, the process being analogous to true fermentation. The evolution of the gas is essential to the action.

There is at present little, if any, evidence of such action during the clarification stage. This is borne out by Messrs. Crawford and Bartow, who, in 1916, at the University of Illinois, found that the carbon dioxide content of the effluent air remained low for two or three hours, after which it considerably increased, and they conclude by saying: "Strong bacterial action does not take place for the first few hours." It is possible that fermentation may take place with more or less vigor at later stages.

Proteolysis.—While there may be some slight hydrolysis of proteins during clarification, it seems unlikely that there is any extensive splitting of proteins during this stage.

The albuminoid nitrogen elimination curve certainly follows very closely the three minutes oxygen absorption curve, but since there is in the ultimate result an accumulation of albuminoid nitrogen as represented by surplus sludge, hydrolysis or destruction can only be slight. Again when, under usually anaerobic conditions, hydrolysis of proteins (i. e., putrefaction) does occur, there is generally (if not invariably) production of ammonia, and were there extensive hydrolysis of proteins at this stage there would almost of necessity be an increase of ammoniacal nitrogen.

In practice, however, there is no increase of ammoniacal nitrogen in the clarification stage, but rather (if the sludge is capable of nitrification), a diminution, from which it follows that if there really is hydrolysis of proteins at this stage, it must be assumed that the ammonia produced (and the alkalinity resulting), must be removed or destroyed as quickly as produced.

Direct Cell Action.—In regard to the suggestion of direct cell action, i. e., absorption of the impurity through the cell walls of living micro-organisms, a few observations may be given.

Direct cell absorption would be by osmosis if bacteria are the micro-organisms operating. It is thus extremely unlikely that colloidal matter could be absorbed directly into the cell, although it is true that the living cell could, and probably does, absorb matters from true solution, but enzymic action would be necessary before the colloidal matters were broken down to a suitable condition for direct absorption. If bacteria are responsible for clarification, it should be possible to prepare the enzyme they secrete, and the enzyme (or enzymes) could be expected to perform the work in sterile conditions and in the absence of the bacteria.

Any action involving catalysis or enzyme action, removal, coagulation, or even presence of colloidal matter; or any action involving great areas of surfaces, may often with advantage be examined in the light of our present knowledge of adsorption, the mathematical theory of which was worked out by Willard Gibbs and independently by Sir J. J. Thomson, and may be stated in the form of the adsorption equation.

When—

X = the amount of substance removed (by adsorption).

M = mass of adsorbent in grams (really area of surface is the factor involved).

C = the equilibrium concentration, i.e., the amount of substance left.

a = a constant for the substance being removed.

*The three minutes figures for settled sewage and effluent from sludge (interstitia liquid) were 1.88 and 0.56 respectively.

n = a constant for the adsorbent.

$$\frac{X}{M} = a\,C^{\frac{1}{n}}$$

or $X = aM\sqrt[n]{C}$ or in words:

The amount of substance removed by unit quantity of an adsorbent varies according to:

1. The nature of the substance being removed.
2. The adsorbent employed.
3. The nth root of the equilibrium concentration. The value of n is usually between 2 and 10.

Since the amount of substance removed depends upon the nth root of the equilibrium concentration, adsorption reactions are much less dependent on initial concentration than ordinary chemical reactions, and adsorption goes on quite effectively in very dilute solutions; in fact, the adsorption equation is only accurate for dilute solutions.

Experiment T.48.—Sewage had been settled overnight.

Into separate 500 c.c. cylinders were placed the following mixtures:

(a) 25 c.c. sludge plus 25 c.c. interstitial effluent plus 450 c.c. sewage.
(b) 50 c.c. sludge plus 450 c.c. sewage.
(c) 50 c.c. sludge plus 337.5 c.c. sewage plus 112.5 c.c. 22½ per cent distilled water, 10 per cent.
(d) 50 c.c. sludge plus 225 c.c. sewage plus 225 c.c. distilled water.
(e) 50 c.c. sludge plus 112.5 c.c. sewage plus 337.5 c.c. distilled water.

The mixtures in the cylinders were then agitated by means of a slow stream of air bubbles sufficient only to keep the sludge from settling, but avoiding aeration to any extent. The bubbles were admitted through open-ended glass tubes of about the same diameter, and each supply was adjusted to about two bubbles per second.

After half an hour of agitation the air supply tubes were removed, and the sludge allowed to settle for one hour, at the end of which the supernatant liquid was decanted off and examined.

Oxygen Absorbed in Three Minutes—Parts per 100,000

Settled Sewage 3.02 parts per 100,000.
Settled Sewage after "Clarification Test" 2.16 parts per 100,000.
Effluents after half-hour agitation and 1 hour settlement.
10 per cent sludge with various dilutions of settled sewage.

	O Abs. in 3 min. C	Log. 10C.	Amount removed X	Log. 10X.
(a) 90 per cent S. S., 5 per cent interstitial water, 5 per cent sludge	2.52	1.4014	0.50	1.0000
(b) 90 per cent S. S., 10 per cent sludge	2.14	1.3304	0.88	.9445
(c) 67½ per cent S. S., 22½ per cent distilled water, 10 per cent sludge	1.68	1.2253	0.59	.7671
(d) 45 per cent S. S., 45 per cent distilled water, 10 per cent sludge	1.12	1.0492	0.39	.5911
(e) 22½ per cent S. S., 66½ per cent distilled water, 10 per cent sludge	0.60	.7782	0.16	.1903

If $\log. C$ and $\log \frac{X}{M}$ (or 10^{C} and $10^{\frac{X}{M}}$ for convenience) be plotted the curve is almost a straight line. This signifies that the clarification action approximately follows the adsorption equation. This result was confirmed by repetition of the experiment on a number of occasions. Different amounts of sludge and different times of agitation were employed, but the adsorption equation was fairly closely applicable.

The classes of reactions already known to follow this equation are:

1. True adsorptions, e.g., by charcoal or other similar well-known adsorbents.
2. Catalytic actions.
3. Enzymic actions.

Knowing that the adsorption formula is applicable, one is enabled to understand why the reaction can efficiently take place even in such very dilute mixtures as ordinary sewage, for if the supply of adsorptive or catalytic surface (or the amount of enzyme) is adequate, the initial concentration of the sewage has little effect on the equilibrium concentration, i.e., the amount of impurity left. Further, adsorption, catalysis, and enzyme action are all surface actions, and as such depend on the initial state of the active surfaces. This being so, there is an obvious necessity for a reactivation stage during which stage the active surface is renewed.

The agreement with the adsorption formula, loss of activity during clarification and restoration of this power of clarification during re-aeration leads to the important inference that the real biological work is done during re-aeration when the enzymes (and perhaps other products) are produced, whilst the actual clarification stage represents little more than a physical or chemical reaction of the enzymes.

Experience on Percolating Beds.—It is highly desirable in studying the activated sludge process that the 30 years or so of research and experience on percolating beds should not be lost sight of, and an experiment of Scott-Moncrieff throws very great light on the theory of both percolating filters and of the activated sludge process. In 1898 he constructed a filter of superimposed trays of media, and found that if the sequence of the trays was altered the action of the filter was impeded. Not until the original conditions were again established could proper purification be obtained.

We know today that clarification takes place in the upper part of the percolating filter and that nitrification occurs below. The percolating bed, then, in a fairly efficient manner separates the clarification and nitrification stages.

When Scott-Moncrieff tried to reverse the order of the stages he was obviously trying to reverse an order which had naturally established itself, and we may be very sure that there must be some sound reasons for the national establishment of this particular order of stages. Study of these reasons cannot fail to be of great importance.

Stages of the Activated Sludge Process.—It seems almost impossible to avoid the inference that the activated sludge process should be separated into stages for the more efficient operation of each stage.

The stages which suggest themselves now are:

1. Clarification.
2. Reactivation of restoration of the powers of clarification.
3. Nitrification.
4. Reactivation of the special nitrifying sludge (if possible).

Although logical to split the process into stages, it must, of course, be recognized that economic considerations must prevail, and until we have learned to conduct each stage at its maximum speed and efficiency, it may be cheaper to carry on with a comparatively slow combined stage process.

Sewage Effluent Tasted Good, Anyway

The Ohio Health News of July 15 is responsible for the following:

"From an isolated school district in the northern part of the state, where the board of education, some time ago, installed sewage treatment works, comes an authenticated story of two fishermen who drank of the effluent and found it good. According to the clerk of the board of education, two men were fishing in the stream into which the effluent drains through a tile. They noticed some clear water flowing through the tile, and drank of it. Going up through the farm to the house, they commented to the farmer on the excellence of the water, and asked him if it came from a spring. It was about the best water they ever drank, they said, and they remarked 'how nice it would be' if they could have such water piped into their homes in the city.

"When they were told where it originated, the water did not seem quite so attractive to them for drinking purposes—but that is a matter of esthetics."

Forestry to Protect Reservoirs

The City Waterworks Department of Akron, O., has developed a transplant nursery in which more than 200,000 seedling trees are growing to a size that will enable them to compete with heavy sod, according to reports to the United States Forest Service. In Barberton, O., the City Waterworks Department began planting on a large scale this year, and plans, along with the reforesting of idle land, to develop a wide shelter belt of pine or spruce all around the large city reservoir. Such a shelter belt prevents much debris from being carried into the water, in addition to acting as a soil binder.

Qualifying Bidders on Public Works

Report of Committee of City Engineers Association of New York State

The prequalification of bidders on public works was recommended by a committee of the City Engineers Association of New York State in a report presented Sept. 27 at the fall meeting of the association. The committee consisted of Harry R. Hayes, chairman, Albany, N. Y.; M. W. Plumb, city engineer, Malone, N. Y.; and Leonard Bergman, city engineer, Jamestown, N. Y. The report and the proposed law follow in full:

Your committee feels that it is an essential duty of a public official to endeavor to eliminate some of the many difficulties which now attend the administration of public works. We appreciate that it is in the interest of the public that every effort should be made to guarantee the prosecution of public work with the greatest degree of efficiency. Losses, delays and inconvenience to the public have been seriously encountered on many public construction projects.

The cause, in many instances of unsatisfactory performance of public work, is due to the fact that the successful bidder is not competent to thoroughly undertake the contract, and lacks either the professional skill, organization, or financial ability to properly complete the project.

Such situations are the result of the present system of awarding contracts to any concern who can furnish a bond. The furnishing of a bond does not in any way guarantee the responsibility of a contractor. The bonding companies have repeatedly made such assertion. The bond is only an assurance that if the contractor fails that the bonding company will assume the obligation of the contract.

The courts have held in numerous instances that it is the plain duty of the contracting public body to investigate the qualifications of a bidder before making an award. This right has not been very generally exercised in this state. Possibly due to the different interpretations of the word "responsibility" as applying to public contracts and because the laws pertaining to the award of public contracts have not definitely expressed the authority which the courts have held that public officials do possess.

It is the opinion of your committee that the policy of qualifying bidders should be adopted in some form. There are two methods which may be adopted. Either to examine the qualifications of a bidder before proposals are received or to determine them after the receipt of bids. In either method the plan of investigation could follow that outlined in the "Standard Questionnaire" recommended by "The Joint Conference on Construction Practices." This conference included committees from: American Association of State Highway Officials, American Institute of Architects, American Institute of Consulting Engineers, American Society of Mechanical Engineers, American Society of Civil Engineers, American Society for Municipal Improvements, Associated General Contractors of America, Highway Industries Exhibitors Association, National Association of Casualty and Surety Agents, Surety Association of America.

Your committee feels that every public body should have some plan whereby the fitness of a bidder to assume a specific contract can be determined. To be most effective, however, the qualifying procedure should be carried out before the bidder is allowed to obtain plans and specifications.

This system avoids such unpleasantness as charges of favoritism when it becomes necessary to reject the bid of an unqualified contractor after the proposals have been received. It assures the contractor the award if his bid is low. It gives the public body the opportunity to establish a qualified list of contractors and to arrange them in classes according to the magnitude or size of the contracts upon which they can qualify.

Your committee, therefore, believes that the most satisfactory system of qualification is the one which requires it prior to the reception of bids and therefore, recommend the approval of the following law.

Proposed Law for Prequalification of Bidders

1. Every officer of the State government, or of any city who is charged with the duty of receiving bids for or awarding a contract for the construction of a public improvement shall, before furnishing plans or specifications or proposals therefor to any prospective bidder desiring to submit a proposal for the construction of such improvement, require that person to submit a full and complete statement, duly verified, of his financial ability, equipment, experience in the construction of public improvements, and of such other matters as the officer may require to assist him in determining the qualifications of that person to undertake and fully perform, in a satisfactory manner, the work contemplated. Such statement shall be filed with the written answers to questions propounded in a standard form of questionnaire to be furnished by the officer to all prospective bidders, and shall be filed with the officer not less than five days prior to the day upon which bids are to be opened.

2. Before the bids submitted for the construction of a public improvement are opened, the officer charged with the duty of awarding the contract for the construction thereof shall consider the statements so filed and determine to his satisfaction those prospective bidders who are duly qualified to undertake and fully perform in a satisfactory manner, the work required; and no contract for the construction of a public improvement shall be awarded to any person, who in the opinion of the officer, is not thoroughly qualified to undertake and fully perform the work in a satisfactory manner, or who has not filed the statement as provided herein.

3. The officer may, at any time after due consideration of the statement filed by any prospective bidder, notify such bidder that he is qualified or not qualified, as the case may be, to undertake and fully perform, in a satisfactory manner, the work contemplated, and it shall be the duty of the officer to make a public announcement, immediately before the bids are opened, of such persons to whom plans, specifications or proposals have been furnished who are deemed to be fully qualified to satisfactorily perform the work required.

4. When any one person shall be the low bidder on two or more contracts for the construction of public improvements neither of which has been awarded, and such person is not in the opinion of the officer, qualified to undertake and fully perform, in a satisfactory manner, the work contemplated under all of such contracts, the officer shall require that person to immediately withdraw one or more of his bids and shall award to that person only such contract or contracts as he shall deem qualified to undertake and perform.

5. No action or proceeding of any nature or description out of any court of competent jurisdiction shall lie against any officer of the state government, or of any city, because of his refusal to award to any person a contract for the construction of a public improvement for the satisfactory performance of which such person is not, in the opinion of the officer, fully qualified, or who has failed to comply with the provisions of this chapter.

6. The term "person" as used herein, means any individual, co-partnership, association, corporation, or joint stock company, their lessees, trustees or receivers.

The term "officer" as used herein, means any officer, board, commission, committee, department or other branch or bureau of the state government, or of any city.

7. This chapter shall apply only to contracts for public improvements, proposals for the construction of which are required to be advertised for by law.

The term "public improvement," as used herein, shall mean an improvement upon any real estate belonging to the state, or to any city.

8. This act shall take effect immediately.

Results of Experiments in Determination of Biochemical Oxygen Demand

Paper Presented March 23 before
New Jersey Sewage Works Association

By LEROY FORMAN

Senior Chemist, Bureau of Engineering, New Jersey State Department of Health

THE biochemical oxygen demand determination of crude sewage, sewage plant effluents, trade wastes, and polluted streams has become generally recognized as an important test for determining their strength, degree of purification, and character of pollution; and discussions of procedure for carrying out the determination are becoming more and more frequent. At the present time there seems to be a great need for standardizing a procedure whereby uniform and consistent results, that will check, can be obtained.

This was demonstrated to me most forcibly last fall when through necessity a number of bichemical oxygen demand determinations were made up in the field and carried around in a machine three days before they could be brought to the laboratory for completion. The results on raw samples were around 60 parts per million of biochemical oxygen demand, which seemed ridiculous and all out of proportion in view of the apparent strength of the sewage both by appearance and as indicated by the figures obtained in the various other chemical determinations. Soon thereafter, the following experimental work was undertaken, which I believe covers the various factors entering into the biochemical oxygen demand determination.

Temperature of Aeration of Diluting Water and Aging.—Portions of distilled and tap water were aerated at two temperatures, 50 deg. F. and 74 deg. F., and after a few minutes when all visible entrapped air had disappeared their dissolved oxygen content was determined. They were then allowed to stand at room temperature stoppered, and dissolved oxygen determined each day.

The water aerated at 50 deg. F. contained 11.8 parts per million of dissolved oxygen; whereas that aerated at 74 deg. F. contained 9.1 parts per million. After two days the former lost 3 parts of oxygen and the latter 0.8 parts. It required eight days standing at room temperature for the two waters to reach the same oxygen content.

A number of samples from time to time of freshly aerated water were allowed to age a week or more and the rate of loss of dissolved oxygen noted. From 0.4 to 0.7 parts per million were lost within a week with water that was not saturated when aerated. With a strong sewage, 2 per cent is mixed with 98 per cent of dilution water; it is very essential then to have a diluting water that has been sufficiently aged as the results obtained must be multiplied by 50 to obtain the biochemical oxygen demand. Freshly aerated distilled water even though not saturated when put in bottles and incubated at 20 deg. C. loses a certain amount of oxygen.

Temperature of Incubation. — One liter of a 2 per cent solution with each of ten samples of sewage from as many towns was made both with distilled water and Trenton tap water that had been aerated and aged at room temperature for two weeks. Three bottles of about 250 c. c. capacity were filled from each liter and one set was incubated for five days at 10 deg. C., another at 220 deg. C., and the third at 31 deg. C.

It was found that the average variation was 5.06 per cent in the ten samples for each degree centigrade between 10 deg. C. and 22 deg. C. incubating temperatures when distilled water was used for dilution, and 3.90 per cent when tap water was used. Between 22 deg. C. and 31 deg. C. incubating temperatures, the average variation for each degree was 0.91 per cent with distilled water and 0.93 per cent with tap water. It was noted that in nearly every instance dilutions made with tap water seem to give higher results than dilutions made with distilled water.

Results of Using Distilled and Trenton Tap Water For Dilution Purposes. —The two waters were aerated at room temperature (74 deg. F.) and allowed to age two weeks before use. The incubation temperature for the diluted sewages was 20 deg. C. In this series 23 samples of sewage from six towns were used consisting of 10 raw sewage samples, 10 Imhoff tank effluents, 1 sprinkling filter effluent, 1 secondary settling tank effluent, and 1 creek water, all run in duplicate.

The average biochemical oxygen demand for the entire 23 samples was 145 parts per million with distilled water and 180 parts per million with Trenton tap water, an increase of 35 parts per million with tap water. When divided into the different kinds of sewage the results are shown in Table I.

The per cent difference between the distilled and tap waters is about the same for the raw and tank effluents; namely, 24.4 per cent and 24.1 per cent respectively. The figures using the two kinds of water for the secondary treatment effluents are fairly close.

The greatest difference in parts per million of biochemical oxygen demand in the check determinations on the same sample was 30 with distilled water and 20 with tap water; the average with distilled water, 11.1 parts per million, and with tap water, 6.07 parts per million; while standardizing temperature of aeration of dilution water, aging and temperature of incubation shows considerable improvement in obtaining closer checks and more consistent results, tap water gives higher and still more consistent and closer checks. It was then thought that the difference between the pH value of the two waters might be the answer. The pH value of the distilled water used was 7.1 and the tap water 7.4. To check this theory 25 parts per million of acid sodium phosphate and 25 parts per million of basic sodium phosphate were added to two portions of distilled water, the former had a pH of 6.6 and the latter 7.6. Several samples of sewage were then diluted with the above two dilution waters as well as with plain distilled water and also the tap water.

It was found that the average difference of biochemical oxygen demand in the checks on four sewage samples was 45 parts per million with distilled dilution water with a pH of 6.6; 25 parts per million with plain distilled water pH 7.1; 7.5 parts per million with distilled water of 7.6 pH; and 5 parts per million with tap water. Although the average difference in the checks of the biochemical oxygen demand between the samples with distilled water of 7.6 pH and tap water was slight, the tap water gave an average biochemical oxygen demand of the four samples of 175 parts per million and the distilled water of 7.6 pH

Table I

Kind of Sewage	Distilled water	Tap water	Difference	Per cent distilled lower than tap
Average B. O. D. of 10 raw samples	172	214	42	24.4
Average B. O. D. of 10 tank effluent	145	180	35	24.1
B. O. D. of sprinkling filter effluent	72	78	6	8.3
B. O. D. of Secondary settling tank	80	84	4	5.0
B. O. D. creek water	10.4	12.5	2.5	24.0

was only 138 parts per million or a difference of 37 parts per million.

Finally another series was made up using all the information we already had in addition to making up several synthetic dilution waters containing sodium, potassium or calcium bicarbonate in quantities approximating the inorganic mineral content of the Trenton tap water. Seven samples of sewage were diluted in duplicate with each of the following five dilution waters:

(1) Distilled water containing 60 parts per million of Sodium bicarbonate pH 7.7.
(2) Distilled water containing 100 parts per million Calcium chloride pH 7.3.
(3) Distilled water containing 60 parts per million of Potassium bicarbonate pH 7.6.
(4) Distilled water with nothing added pH 7.1.
(5) Trenton tap water containing 75 parts per million. Inorganic salts pH 7.4.

The average difference of biochemical oxygen demand in the duplicate determinations with (1) was 4.3, (2) 8.0, (3) 4.3, (4) 5.0, and (5) 4.3 parts per million respectively.

The average biochemical oxygen demand of the seven sewages in duplicate was as follows:

(1) Distilled water and sodium bicarbonate	162
(2) Distilled water and calcium chloride	182
(3) Distilled water and potassium bicarbonate	186
(4) Distilled water plain	136
(5) Trenton tap water	192

From the above it will be seen that for the most consistent, uniform and also higher results the potash salt is superior to either sodium or calcium salts added to distilled water. It is also interesting to note the very much lower results obtained with plain distilled water than with distilled water to which any of the inorganic salts were added: 136 against 162 for sodium salts, 182 for calcium salts, 186 for potash salt, and 192 for Trenton tap water.

Conclusions.—No single factor alone that was tried in these experiments is responsible for obtaining maximum consistent results that will check, but a combination and close adherence to all factors, temperature of aeration, aging, temperature of incubation, mineralizing and pH are necessary.

Aged tap water of a good quality can be used satisfactorily for diluting purposes at any sewage plant, but when results are desired for the comparison of one effluent with another or many other effluents from various localities, it is advisable to use a uniform diluting water.

For a time it was thought that the nature of the material and the state of activity of the organisms associated with it was the principal factor in obtaining good results. This may still be a factor but is believed overcome or controlled by following the last series of tests.

The greatest factors for obtaining good results in biochemical oxygen demand determinations are: (a) mineralized water, preferably with potash salts, with a pH well on the alkaline side; (b) well aged diluting water; and (c) incubation at a uniform temperature and not below 20 deg. C.

Method Adopted by New Jersey.—In consequence of the above data the following method has been adopted as the tentative method for the determination of biochemical oxygen demand by the Bureau of Engineering, State Department of Health of New Jersey. This procedure gives a practical field method inasmuch as a supply of the aged synthetic dilution water is available in the laboratory.

Court Decisions Regarding Sewage Disposal

From Public Health Reports, July 5, 1929

Order of State Department of Health to City Relative to Sewage Disposal Upheld.—(Ohio Supreme Court; City of Bucyrus v. Department of Health of Ohio et al., 166 N. E. 370, 120 Ohio St. 426, 2 Ohio Bar 10; decided April 24, 1929.) The state department of health, acting under statutory authority and after complaint, investigation, notice, and hearing, ordered the city of Bucyrus to install works or means satisfactory to the state director of health for the collection and disposal of the sewage of the city in a manner to correct and prevent the pollution of the Sandusky River. In a proceeding in error from the department's order, the supreme court stated that all the questions raised were determined by its decision in the case of the State Board of Health v. City of Greenville, decided April 2, 1912, unless the adoption on September 3, 1912, of Article XVIII of the state constitution had so changed the relationship of municipalities to the state as to divest the state of its sovereignty over such municipalities in respect to sanitation within and in the vicinity of such municipalities. Said Article XVIII provided, in part:

> Municipalities shall have the authority to exercise all powers of local self-government and to adopt and enforce within their limits such local police, sanitary, and other similar regulations as are not in conflict with general laws.

The court's view was that the adoption of the article did not change the situation of the municipalities with respect to local sanitary regulations, except that before such adoption they had such power to adopt local sanitary regulations as had been conferred upon them by the legislature and since such adoption they had such power to adopt local sanitary regulations as had not been taken away from them by the legislature in the enactment of general laws. The court said:

> The effect of the constitutional provision granting to municipalities the power to adopt local sanitary regulations is, therefore, no different than though the power had been conferred by legislative enactment instead of constitutional provision; for, if conferred by legislative enactment, the act would be subject at all times to revision or repeal by the legislature. The constitutional provision conferring the power with the limitation that the municipal regulation must not be in conflict with general laws operates to bestow upon the legislature the same power to control sanitation by general laws that it had prior to the adoption of that article. The power conferred by that article is conditioned upon the legislature not having enacted general laws with which the local sanitary regulations of the municipality conflict.

The decision in the Greenville case was adhered to by the court.

With regard to the hearing before the health council, the court made the following observations:

> * * * While the technical rules of a hearing by a court are not required to be strictly observed in hearings before administrative bodies, it is the duty of such bodies to permit a full hearing before administrative bodies, it is the duty of such bodies to permit a full hearing upon all subjects pertinent to the issue, and to base their conclusion upon competent evidence; and such result can better be accomplished by a substantial adherence to the rules observed in hearings in court. In the instant case, the newspaper article was not competent evidence. * * * The reports of the engineers employed by the health department were official in character, authorized by statute, and were competent evidence in such hearing * * *. The city of Bucyrus was entitled to examine and to attempt to impeach such reports and each and every person who assisted in gathering data and compiling such reports. The city of Bucyrus was entitled to present its own witnesses to disprove any of the facts testified to by the witnesses of the complainants, or any of the facts shown in the reports, and was entitled to file such papers in the case as it deemed essential to the preservation of its rights and the preservation of its cause or defense, and was also entitled to make such defense without the filing of an answer. * * *

The department's order was affirmed.

Order of State Health Department Concerning Sewage Disposal Upheld.—(Ohio Supreme Court; State ex rel. Neal, Director of Health v. Williams, Mayor, et al., 166 N. E. 377, 120 Ohio St. 432, 2 Ohio Bar 10; decided April 24, 1929.) In a mandamus action to enforce the laws relating to the pollution of watercourses, the petition charged that the respondents were causing sewage of the city of Delphos to be discharged into certain streams, in violation of statutes, in such quantities and of such character as to pollute the streams, and that this conduct constituted a public nuisance by making the streams a menace to public health and welfare in the vicinity. The petition contained proper allegations necessary to show that, pursuant to complaints filed, an examination of the situation had been made by the state director of health; that a hearing, after due notice, had been held; that findings had been made and respondents notified thereof and directed to make other arrangements, within a specified time, for the proper disposal of sewage in a manner satisfactory to the state health authorities; and that the time fixed had elapsed and respondents had refused to comply with the order.

The respondents challenged the sufficiency of the petition and presented many other issues for the court's consideration, such as the unconstitutionality of the law under which the health department acted, misjoinder of parties, omission of parties, insufficiency of findings made by the health authorities, unreasonableness of the order, and also the claim that, under the home rule provisions of the constitution, the city could not be controlled by the state health department with respect to its disposal of the city's sewage.

The supreme court, which found against the city, said:

> This court is of the opinion that every issue presented by the pleadings and urged in the arguments and briefs of counsel has been fully and completely covered by the decisions of this court, and that there is now nothing further to be said on the subject.

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Our New Title, "Water Works and Sewerage"

A year ago "Water Works" was merged with "Municipal and County Engineering" under the title "Municipal News and Water Works." For 12 years "Water Works" had specialized in the hydraulic field, and it has continued to devote nearly all its space to municipal hydraulics during the past year. This policy of hydraulic specialization is to be continued.

During the past year many of the old readers of "Municipal and County Engineering" have been induced to subscribe for "Roads and Streets," so that they now receive a semi-monthly municipal news service. Published about the first of the month, "Water Works and Sewerage" covers hydraulic and sanitary engineering features, while "Roads and Streets," which is published about the middle of the month, covers the pavement and street features of municipal engineering and contracting.

The third magazine of the Gillette Construction Group is "Engineering and Contracting" which was founded 24 years ago next January by Myron C. Clark and Halbert P. Gillette. This magazine covers bridges, buildings and heavy construction such as railways, irrigation canals, etc. The three magazines together give complete coverage of the civil engineering field and its allied contracting.

Municipal hydraulics, to which "Water Works and Sewerage" is devoted, embraces the allied fields of city water supply and sewage treatment and disposal. It costs about $80 per capita to build a modern water works system and almost an equal sum to build a sewerage system. Since nearly 75 per cent of our people live in incorporated towns and cities, we have about 90,000,000 urban residents. To reproduce their water works and sewers would cost not much less than $1,400,000,000; it would cost fully that if they were all adequately served. Most of the smaller towns have inadequate hydraulic plants and service. The same is true of many of the large cities. Inadequacy of plant is seen wherever water meters are not installed, which unfortunately is the case in all too many instances. The same is true where hard water is not softened, where impure water is not chlorinated and where raw sewage is discharged into streams from which other towns and cities take their water.

There is a vast deal yet to be done by American engineers, superintendents and contractors before our systems of municipal water supply and sewage disposal may be regarded as being satisfactory, either from an economic or from a sanitary point of view.

This magazine was the first American magazine to specialize completely in municipal hydraulics. It is the only magazine devoted solely to water works and sewers. Last June its first Water Works and Sewerage Catalog issue was published, and distributed at the time of the annual convention of the American Water Works Association. Our readers will receive an even larger and more complete book of hydraulic reference data next June.

Predicting Storms by Static

Nearly 180 years ago Benjamin Franklin flew the famous kite whose string brought to earth an electric current from a cloud. He believed that the friction of the air electrified the clouds, and to this day that theory, with a few additions, is generally accepted. It is now believed that the disruption of rain drops also generates electric charges, and that charges so generated may be even more potent than charges produced by friction.

The editor believes this theory to be wrong. Instead of electricity being generated by the clouds, the editor believes that electricity generates the clouds, for he regards all cyclonic air-whirls as electromagnets whose free electrons are rotated by the earth's magnetic fields. Since our storms are all cyclonic, it follows that storms should invariably show electric effects. That this is at least the usual case is indicated by the static that has been found to be caused by many storms.

A. H. Harper, of the research department of the American Telephone and Telegraph Co., recently announced that by aid of two loop aerials connected to radio sets, he has been able to locate the position and trace the track of many storms. For example, a storm center was located northwest of the Great Lakes, Sept. 7, 1928; and six days later it passed near Houlton, Maine, accompanied by lightning. We predict that this radio method of discovering storm centers and tracing their tracks is destined to revolutionize the prediction of storms.

In several articles the editor has given his electromagnetic theory of air-whirls, but it will be very briefly outlined again.

Air contains free electrons. Free electrons tend to rotate around the lines of force of a magnet. The earth is a compound magnet. So is the air above it. Free electrons moving in the same direction in approximately parallel orbits constitute an electromagnet. Hence air, if sufficiently charged with free electrons, is given a whirl. When thus whirling the air-whirl is itself an electromagnet. Since parallel electric currents in the same direction attract one another, the electrons tend to become concentrated in a belt around the whirl center. Hence air flows from the center as well as from the outside toward the whirl belt. Since opposite electric currents repel one another, the whirl-belt expands to a position of equilibrium. The net effect is low barometer near the center of the whirl-belt, but it is not this "law" that causes the air to ascend. Electromagnetic force pushes a cyclonic whirl-belt upward. The air is literally pumped upward by electromagnetic force. The rising air is cooled and tends to precipitate some of its moisture. Electrons act as centers upon which the moisture collects. Clouds form. When the

electromotive force becomes high, relative to the resistance, discharges occur. Moisture in the air is favorable to such discharges. So is great altitude, for as the pressure is reduced more electrons are set free.

Every statement in this last paragraph is founded upon electric theory established by experiment, yet, strangely enough, this theory of storms had not been suggested by any meteorologists and is still regarded with skepticism. Static electric theories had previously been suggested to explain ascending air currents, but they could not account for the magnitude of the barometric changes, and they made no attempt to explain the rotary nature of storms. On the other hand, the editor's electromagnetic theory accounts for every important feature of storms, such as: (1) Rotation, (2) ascent, (3) progression, (4) the subsequent "high" (anticyclonic), (5) electric charge, (6) inflow of the outer air, (7) low barometer at the center, (8) opposite rotation in the northern and southern hemispheres, (9) storm effects of sunspots (which are themselves electromagnets), and (10) the two stormy seasons that center around January and July when the axes of the earth and sun are in the same plane.

In addition to the ten features just named, there are many others that are explained by the electromagnetic theory, and without the aid of any other new theory. Also, although this theory is new, it rests upon facts established by laboratory experiments. None the less it will find "slow sledding," for old theories, however inadequate or incorrect, have the vitality of a cat with its nine lives raised to the ninth power.

The Need of a Large Research Staff in Our Weather Bureau

When our government follows the example of our great corporations and organizes a large research staff to investigate the causes of weather changes, we may hope for satisfactory progress in the art of weather forecasting. It will be replied by the Weather Bureau that much progress has been made, and that they are conducting researches; but the fact remains that although that bureau has been in existence nearly 60 years, it confesses inability to forecast weather much more than a week in advance.

A few years ago, Prof. Cleveland Abbe, then editor of the "Monthly Weather Review" (the government magazine) wrote the article on meteorology that was published in the Encyclopedia Britannica. Speaking of the influence of sunspots and other cosmical forces on weather, he said: "But, in the writer's judgment, these matters, while curious and interesting, have no appreciable bearing on the current important questions of atmospheric mechanics. . . . The leading meteorologists have relegated such questions to the care of theoretical astronomers and physicists until our knowledge is more firmly established." And he goes on to add that "it would be folly to spend time" on a study of cosmical causes of weather until a better knowledge is attained of the earthly causes which present such a "bewildering maze of problems." Thus, while admitting the existence of a "bewildering maze" he calls it folly to seek extrication from that maze by study of sunspot effects and the like!

That Prof. Abbe's spirit still is potent in our Weather Bureau was recently made clear to the writer when the editor of the Monthly Weather Review declined even to look at a manuscript that an hydraulic engineer offered to submit on the relation of sunspots to rainfall. That editor was so cocksure that no one could possibly discover any new and important relationship between sunspots and weather that he would not even spend a few minutes of his time reading the manuscript.

Not many months ago Prof. C. F. Marion, chief of the Weather Bureau, gave an interview to the newspapers in which he held up to ridicule all attempts at long distance weather forecasting. He was quoted as saying: "When long distance weather forecasting is on a scientific basis, rather than a foundation of mere guesswork, such forecasts will be made by the weather bureau." So, with "admirable scientific caution," he patiently waits, as his predecessors have waited for 58 years, for someone to show them how to make long distance forecasts. But his is like the adamantine mug of the man in the show window: "Make him smile and we will pay you $10." He dares anyone to change his expression of indifference or the belief that engenders it.

Meteorologists, according to Prof. Abbe, should wait for astronomers to pave a definite relationship between sunspots and weather. Well, Prof. Douglass (an astronomer) did that very thing nearly a generation ago, and so did Prof. Huntington (a geographer), and so did Prof. DeGeer (a geologist), but Prof. Marvin (the meteorologist) is still waiting. The clues that such scientists have furnished have not been diligently followed up by the Weather Bureau. It refuses to "smile," because it is resolved not to "smile." Small wonder that Father Ricard, the Jesuit astronomer and meteorologist, recently said that the heads of the Weather Bureau are suffering from "sleeping sickness."

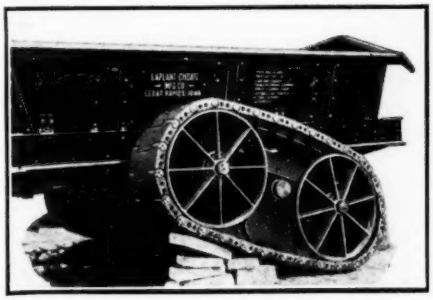
So far as farmers and hydraulic engineers are concerned—and we are now speaking in behalf of the latter—the Weather Bureau has failed to make any progress in solving the important problem of long-distance weather forecasting. We venture to say that in a year's time a committee of hydraulic engineers would make more progress in solving this problem than the Weather Bureau has made in the 58 years since it was founded.

We do not wish to be understood as condemning what the Weather Bureau has done, but what it has failed to do. Its "Monthly Weather Review" is a valuable magazine. If it had never done more than recently to translate and reprint Prof. Fritz's old (1893) article on "The Periods of Solar and Terrestrial Phenomena" (M. W. R., October, 1928), it would have justified all the money spent in publishing the magazine since its inception. The same is true of Homer W. Clough's recent article (M. W. R., July, 1928) on the 28-mo. solar and weather cycle. Mr. Clough, we believe, is one of the Weather Bureau staff. What we urge is the organization of a large staff of competent researchers whose sole function shall be to try to fathom all the mysteries of weather phenomena. Such a staff would welcome aid from every source, looking, as it would, with friendly eye upon any suggestion, however fanciful it might seem, and enlisting the aid of men in every branch of pure and applied science. The trained researcher is never skeptical. On the contrary, he knows that from the most fantastical hypotheses the greatest discoveries have so often sprung, that he bids every Columbus "God-speed."

H. P. Gillette

La Plant-Choate Track-Type Wagon

La Plant-Choate Manufacturing Co., Cedar Rapids, Ia., have placed on the market a wagon track that is a big step ahead in their line of equipment. These



La Plant-Choate Crawler Wagon

new tracks are manufactured under license from the Caterpillar Tractor Co., San Leandro, Calif., and Peoria, Ill. Write La Plant-Choate for catalogs or see their nearest dealer for literature and demonstration.

Witte Produces Newly Designed Engine Powered Diaphragm Pumps

For jobs where accumulations of muddy, trashy water must be pumped, two specially designed, heavy-duty, engine-powered diaphragm pumpers are now offered to the construction and engineering field by the Witte Engine Works, Kansas City, Mo.

Each of these pumpers is a complete portable unit, direct, single reduction, gear-drive engine, pump and transmission being compactly and rigidly mounted on a rugged, all-steel truck. Capacities, per hour are, it is claimed, for the one outfit (No. 10), up to 5,000 gallons per hour, and for the other (No. 12 outfit with two intakes for working in one or two excavations at the same time), up to 10,000 gallons. Pumps are self-priming, and can be furnished with flexible hose and foot valve to water connection.

All bearings on engines, pumps and transmissions have compression grease cup lubrication. The engine crank case is enclosed, thus protecting moving parts from all dirt and sand. Gears are steel alloy and machine cut. Pump valves are wing-guided poppet type and have replaceable rubber facings. Valve seats are carefully machined. Lever-arm bearings have replaceable bronze bushings.

Reliable, low-cost power is provided by the all-fuel Witte throttling governor type "H" engine, WICO magneto ignition, weather and water proof. For general power use, the engine is quickly detachable from the pump, and drive pulleys can be put on the extended crank shaft on both sides.

The pumps are now available through the regular trade channels, as also are the various sizes and types of internal combustion engines which the Witte Company has developed in its half-century of exclusive engine manufacturing. The line now embraces units of 2, 3, 4, 6, 8 and 12 hp., and a special heavy-duty type in 20 and 30 hp. sizes, including power deep well and pressure pumps and power saws.

High-Pressure Double-Deck Compound Turbine-Generator

Several unusual or new features will be incorporated in two steam turbine generators which are to be added to the generating facilities of the Pacific Gas & Electric Co., San Francisco. The two machines, each rated at 50,000 kilowatts, will be the first of the new "double-deck compound" type, and will be fueled with natural gas piped from a source 240 miles away.

It is claimed the station will be one of the most efficient in the world, the result both of employing 1,250-lb. boilers and using natural gas as fuel. Each main 1,200-lb. turbine unit, of General Electric manufacture, consists of a high-pressure element operating at 3,600 r.p.m. and a low-pressure element operating at 1,800 r.p.m. The turbines, rated at 50,000 kilowatts each, are to be suitable for a maximum output of 62,000 kilowatts. Provision is made so that the low-pressure turbine can be operated from the high-pressure boilers with the high-pressure turbine shut down.

A new type of construction will be used, in that the high-pressure turbine and generator will be mounted on top of the low-pressure generator, thereby saving the foundation and the floor space ordinarily required for the high-pressure turbine. The result is a very compact unit.

In addition to the main turbines, two General Electric auxiliary turbines are included for driving the boiler feed pumps. These pumps, used with high-pressure boilers, absorb considerable energy, and therefore these turbines are much larger than usual. They are of the two-unit type, composed of condensing and non-condensing elements. The condensing element is coupled to one end of the pump and takes steam from the present 300-lb. boilers; the non-condensing element is coupled to the other end of the pump and takes steam from the cross-over between the main turbines. This arrangement permits the two elements of the turbines to be operated at times independently and at other times together, so as to maintain at all loads the most economical heat balance on the installation as a whole.

Lincoln New Kathode Welding Electrode

Extensive research and experimentation by the Lincoln research laboratories has made possible the offering to the trade of the New Kathode welding electrode by The Lincoln Electric Company, Cleveland, O. The electrode is manufactured for the arc welding of mild steel and for cast iron repair work.

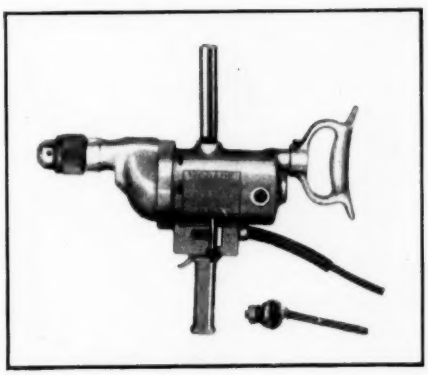
The composition of the New Kathode welding electrode, as well as the special treatment given in its manufacture, imparts qualities heretofore lacking in the usual electrode. Flowing easily with freedom from sputtering, the new electrode produces clean welds with minimum slag and oxidation. The high heat permissible for use with this fast running electrode makes possible increased welding speed. The quality of the weld is not sacrificed for speed of welding, as the New Kathode electrode fuses easily. The resulting weld on steel is soft and readily machinable.

The New Kathode electrode is manufactured in stock lengths of 14 and 24 inches. To provide best possible protection, during shipment, the rod is packed in metal containers holding 50 pounds each.

New "Wodack" All Purpose Drill

The new Wodack all purpose portable electric drill, made by the Wodack Electric Tool Corporation, 4627 West Huron street, Chicago, combines lightness with power and performs in an unlimited range of drilling requirements.

A General Electric motor of ample reserve power is built in for direct or alternating current of 60 cycles or less, 110-125 or 220-250 volts as desired. An oversize double pole, trigger switch in convenient position, insures long life. High grade ball and roller bear-

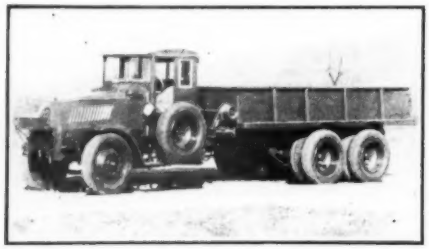


The New WODAK All Purpose Drill

ings are used, the heavy thrust loads being carried by Timken roller bearings. Hardened gears are simply assembled, grease compartments are designed for long periods of operation, and correct ventilation is provided for by an oversize fan for quick cooling during idle running.

New Mack Super-Duty Truck

Modern highway transportation requires speed either as a competitive element in the business of hauling or as the transportation element where it is one of the distribution or manufacturing processes in other industries.



Mack's New 6-Cylinder Super-Duty Truck

The road speed necessary to meet the demands for rapid delivery service has, heretofore, been obtained by reducing load capacities, using pneumatic tires and higher gear ratios with existing engines. This reduced the most essential element of hauling economy, which is capacity.

Mack now introduces the Super-Duty line of trucks, two models of which are designed to carry great loads at high speed.

The AP 4-wheeler and the AP 6-wheeler will carry from 7½ to 10 ton truck loads at 30 miles per hour and climb 20 per cent grades with ease provided the footing is given. They will haul 35 ton drawbar loads at 25 miles per hour. These massive AP trucks are powered by 6-cylinder high compression engines of 150 horsepower.

When 70,000 pounds or 35 tons can be hauled with one engine and one driver at a steady speed of 25 miles per hour, the tremendous possibilities in low cost transportation is evident.

Twenty-five miles per hour will generally equal the average speed of lighter vehicles so that the service element of speed is combined in the Mack Super-Duty line with the economy of great capacity.

In addition to the AP model, the Super-Duty line includes the famous AC model with a new high compression engine and six wheels. This Super-Duty vehicle is designed, not for speed, but for hauling heavier loads under the difficult conditions encountered in the earth moving industry and other fields where the greater traction and better load distribution of six wheelers is recognized.

The most outstanding innovation, in addition to the tremendous power in the model AP, is the six-wheel feature with rear, four-wheel drive. In this, Mack has retained its characteristic heavy duty feature—chain drive.

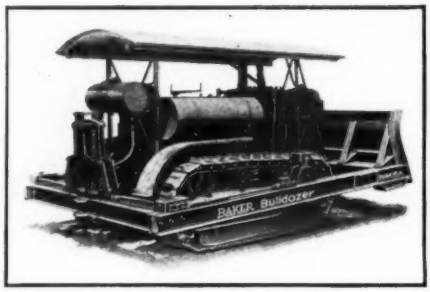
The rear truck consists of two dead axles mounted through rubber shock insulators to massive spring tips. The spring is anchored at its base to a horizontal torque bar mounted in the frame so that the load is equally distributed between the two rear axles. This distribution which is the most desirable from a standpoint of road impact, can be obtained on the Mack Super-Duty models because the tractive resistance of all four wheels is effective through four-wheel drive.

The drive is effected by means of four sets of driving chains, each set of rear wheels driven by an independent jackshaft. Brakes are on all rear wheels as well.

Baker Bulldozer Announced

The Baker Mfg. Company, Springfield, Ill., has just developed the Baker hydraulic bulldozers for 30 and 60 Caterpillar tractors.

The frame of the bulldozer surrounds the tractor, mounted and pivoted at the rear of the tractor draw bar and on outer ends of the rear axle of the tractor. The pull is thus at three points in a straight line with even distribution of power. Heavy and rigid construction of both moldboard and frame give the bulldozer exceptional strength.



Bulldozer Developed by Baker Mfg. Co.

The raising and lowering of the blade is accomplished by means of an oil-operated gear pump, directly connected to the power drive shaft of the tractor, which operates a hydraulic ram. Mounted forward of the center of the truck frame on each side is a heavy steel bracket clamped to the truck frame of the tractor. At the top of each bracket is a roller chain which operates over a cast steel sprocket mounted in suitable bearings on the side of the frame. As the roller chain is connected to the hydraulic ram at the rear, the vertical action of the ram lifts the moldboard off the ground to the required height.

A hand lever conveniently located near the tractor operator's seat controls the raising and lowering of the blade.

The particular advantages claimed for the Baker bulldozers are: (1) Ability to operate various distances below the level of the track of the tractor, (2) Higher elevation of the blade, (3) Keeping a more nearly level grade, (4) Strength and (5) Easier operation.

Hyatt Develops New Bearing

To satisfy an increasing demand for a roller bearing interchangeable with standard S. A. E. single row ball bearings, but having greater load capacity, the Hyatt Roller Bearing Company of Newark, N. J., are now manufacturing single row radial bearings.

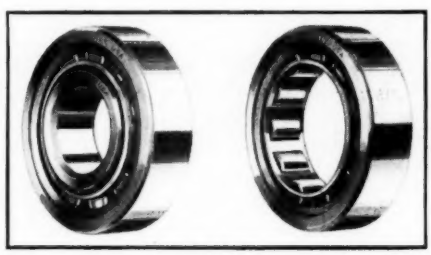
This new line of Hyatt single row radial bearings, made up of solid rollers, is not intended to replace the standard Hyatt roller bearing which uses spirally wound rollers, but is offered as a supplement to it, for positions in which space limitations exist, and loads beyond the capacity of ball bearings must be sustained.

The design employed is one in which the rollers are permanently retained with the outer race, the inner race being separable.

A separator, floating on the rollers, spaces them properly, and heat treated end rings retain them endwise within the outer race. The end rings and separator function to keep the rollers in proper alignment insuring positive contact along their full length. This full line contact of the rollers, the Hyatt Company states, enables their single row radial bearings to sustain greater loads than can safely be carried by ball bearings of equivalent sizes which have only spot or point contact between balls and races.

The manufacturer states that the rollers and races of this bearing are made of a special analysis chrome nickel alloy steel, and the end rings are of vanadium steel to eliminate any wear by the ends of the rollers. The roller separator is so made that the pockets are absolutely parallel and equally spaced, thus assuring uniform load distribution on the rollers.

It is further stated that the possible separation of this bearing into two parts, the inner race being removable, offers opportunities of developing more economical methods of assembling for all applications with or without the inner race. The roller ends are sufficiently rounded to facilitate assembly where the inner race is not used and both the outer and inner races are chamfered at one end.



The Hyatt Single Row Radial Bearing With the Inner Race and With the Inner Race Removed to Show Roller Construction

Hyatt single row radial bearings are now in regular production in a range of sizes sufficient to cover the needs of the present for this type of bearing.

DISTRIBUTOR NEWS

The Distributor's Department in the Gillette Construction Group

Clark Operates Model Foundry
Interior View of the Iron Foundry Operated by H. W. Clark, Mattoon, Ill., Manufacturers of Clark Water Works Necessities. This Is One of the Most Complete and Up-to-Date Gray Iron Foundries in the Middle West. The Building Is of Special Design to Accommodate the Travelling Crane Equipment, and Laid Out for Economical and Efficient Production.
Nothing Is Done by Hand That Can Be Done by Automatic Machines from the Preparation of the Sand to the Ramming or "Squeezing" of Patterns in the Flask. The Cupola Capacity Is Twenty-four Tons a Day.

General Electric Holds Board Meeting on Electric Yacht

A recent meeting of the board of directors of the General Electric Company was held abroad the "Viking," a new 263-foot electric yacht owned by George F. Baker, Jr. The yacht was boarded at 26th Street and East River and cruised along Long Island Sound.

At the meeting announcement was made of the retirement of Allen H. Jackson, who has been general counsel and vice-president of the company since 1922. Mr. Darius E. Peck was elected to fill the position left vacant by Mr. Jackson's resignation, and the president of the company, Mr. Gerard Swope, stated the company would still be able to call upon Mr. Jackson in matters requiring consultation.

Mr. Peck, the newly elected vice-president, is a graduate of Yale University, and practiced law in New York City from 1902 until 1921, when he became a member of the law department of General Electric Company and moved to Schenectady.

The retiring vice-president, Mr. Jackson, joined the General Electric Company in 1902, as one of its attorneys. In 1922, the year in which Gerard Swope succeeded E. W. Rice, Jr., as president of the company and Owen D. Young succeeded the late Charles A. Coffin as chairman of the board, Mr. Jackson was appointed vice-president and general counsel.

The yacht on which the directors met, was electrified by the General Electric Company and exemplifies the first pleasure craft to be equipped with turbine electric propulsion, according to statement of one of the company's officials. The yacht was designed by Theodore D. Wells and built by the New Port News Shipbuilding and Drydock Company. It is of twin-screw type, each propeller being driven by a 1,300 shaft-horsepower motor from electric power supplied by two turbine generators. All auxiliaries are electrically operated.

The Wagner Electric Corporation of St. Louis, Mo., has moved its Cleveland service station and branch sales office to a new building at 3756 Carnegie Ave. The Cleveland office handles the entire Wagner line of motors, transformers, fans and Lockheed Hydraulic brakes, not only as a branch sales office, but also as a repair shop and service station.

North Western Buys Graver Softeners

The Chicago and North Western Railway Co. has contracted with Graver Corp., East Chicago, Ind., for three complete Graver Water Softening plants. The sizes and locations of these plants are: Clyman Jct., Wis., 20,000 gal. per hour, with additional storage for 60,000 gal. South Janesville, Wis., 15,000 gal. per hour, with additional storage for 35,000 gal. Jefferson Jct., Wis., 12,500 gal. per hour, with additional storage for 50,000 gal.

All of these plants will be equipped with the new Graver chemical control equipment, brought out within the past year. The Graver control mechanism consists primarily of a standard commercial water meter installed in the inlet line to the softener. This meter is attached to the feed pipe in the chemical tank and allows the chemicals to flow into the softener in direct proportion to the water.

The North Western has also contracted with Graver Corporation for an additional tank 21 ft. dia. x 52 ft. high to enlarge the capacity of the Graver Softener installed at Boone, Ia., several years ago.

Continental Motors an Exhibitor at Aeronautics Exposition

C. P. Russell, aeronautical sales manager for the Continental Motors Corporation of Muskegon, Mich., together with F. T. Gould, was in charge of Model A70 160 hp. radial engine and component parts at the Aeronautical Exposition held in Cleveland recently in conjunction with the National Air Races.

At the time this item went to press it was announced that the Continental powered plane would make a number of trips between Cleveland and Detroit during the races to transport members of the aeronautical division to Cleveland.

Bendix Aviation Takes on New Subsidiary

The East Orange plant of the Eclipse Machine Company has been taken over as a subsidiary unit of the Bendix Aviation Corporation and is to be known as the Eclipse Aviation Corporation.

This plant will continue to produce a complete line of starters for aircraft, as well as other aircraft equipment and aeronautical devices now being developed.

Schwanhausser Goes to Buffalo as Manager for Worthington

Mr. E. J. Schwanhausser, who entered the employ of the Worthington Pump and Machinery Corporation while a student at Stevens Institute of Technology, has just been appointed manager of that company's Buffalo works. Mr. Schwanhausser is but 35 years of age, and is one of the youngest executives in the Worthington organization.

E. J. Schwanhausser, Recently Made Manager Buffalo Works for Worthington Pump and Machinery Corporation

During the summers of 1912, 1913 and 1914, while still in school, he was employed in the various shops and on the testing floors at Harrison, and immediately upon his graduation in 1915, he was made test and erection engineer. He served successively in the condenser engineering department, as machine shop equipment engineer, superintendent of the machine shops, superintendent of field erection department and assistant to the manager.

In 1927 Mr. Schwanhausser was appointed assistant works manager, and it was while holding this position that he was made manager of the Buffalo works.

General Electric Distributing Companies Consolidate

Effective Oct. 1, 1929, the fourteen wholesale distributing corporations owned by the General Electric Company will be consolidated into the General Electric Supply Corporation (of Delaware), according to recent announcement. These companies have for many years distributed General Electric products and the plan, it is said, involves no change of ownership. The consolidated corporation will be in a much better position to offer nation-wide service through its ability to give service from any one of seventy-six houses, through interchangeability of stocks, and speedier and more economical operation.

The tentative organization plans indicate corporate officers and directors as follows:

Gerard Swope, chairman of board; C. E. Patterson, president and director; J. L. Buchanan, executive vice-president and director; J. G. Johannesen, vice-president, eastern region, and director; D. E. Harris, vice-president, western region, and director; N. R. Birge, A. D. Cameron, H. C. Houck, J. E. Kewley, G. C. Osborn, T. K. Quinn, E. O. Shreve, C. E. Wilson, directors; L. R. Link, secretary-treasurer; L. M. Nichols, comptroller.

Gardner-Denver Representatives Sent Far Afield

Two foreign branch managers of the Gardner-Denver Co. left the United States this week to take charge of their respective offices.

Ralph Scott, formerly sales manager of the drill division of the company, is enroute to London where he is to be stationed permanently. W. G. Agnew, who was until recently the Gardner-Denver sales representative in Arizona, leaves for Lima, Peru, to take charge of the office there.

The Gardner-Denver Co. manufactures rock drills, air compressors, slush pumps, drill sharpeners, high pressure drill steel forges and kindred machinery. Its main plants are located in Denver, Colo., Quincy, Ill., and La Grange, Mo.

Harold Smith Becomes Vice-President of Westinghouse

At a recent meeting of the board of directors of the Westinghouse Electric and Manufacturing Company, Mr. Harold Smith, general solicitor of the company, was elected vice-president.

Mr. Smith entered the legal department of Westinghouse in 1919, becoming general solicitor in 1926. Prior to that time he was engaged in the practice of law in Chicago, where he was a member of the firm of Glennon, Cary and Walker. He is a member of the state bars of New York and Illinois, and holds law degrees from Northwestern and Yale Universities.

His office will be in the Westinghouse Building, 150 Broadway, New York.

W. A. Gluesing Will Handle General Electric Booth at Petroleum Exposition

Arc welding and atomic hydrogen welding sets will be shown in operation, as well as motors and control for drilling, pumping and refining together with an educational exhibit from the General Electric laboratories will be on display at the International Petroleum Exposition to be held in Tulsa, Okla., early in October.

"Casey Jones," the toy train which obeys commands transmitted to it through the medium of an ordinary telephone transmitter, will be included in the exhibit which is under the direction of Mr. W. A. Gluesing for the General Electric Company of Schenectady, N. Y.

Riddell Company to Hold Pow Wow

A very enticing looking invitation has been sent out by W. A. Riddell Company for a three-day conference to be held in Bucyrus, Ohio. It is expected that there will be a large attendance made up of the sales organizations throughout the country representing Riddell. The meeting will be held at the Elks Club, Sept. 16, 17 and 18.

In addition to inspecting and watching demonstrations of the new machines and improvements which are to be announced to the trade at the Road Show in Atlantic City in January, it appears from the invitation that golf courses, fishing grounds, baseball fields, and even the lowly horse shoe will come in for due consideration.

The next issue will tell about results accomplished.

Appointed Sales Manager

W. H. Arnold has recently been appointed general sales manager for the Pittsburgh Valve, Foundry & Construction Company, making the fourth man to hold that position since 1900, when the constituent companies of Pittsburgh Valve were incorporated.

Mr. Arnold has been connected with the Pittsburgh company since 1905, and during his first twelve years acquired a thorough and comprehensive knowledge of the valve and piping business through working in the various departments of the plant.

Since 1917 he has been engaged in sales activity, bringing to the merchandising field all his knowledge of the products gained when identified with their manufacture. He is almost universally known not only among the power, industrial and oil interests of the East, but equally as well among the gas and oil interests of the mid-continent.

Thomas W. Hall Joins Fairbanks-Morse Co.

Announcement has been made to the effect that Mr. Thomas W. Hall, an engineer with a broad background of industrial experience and editorial work, has joined the staff of the Fairbanks-Morse organization. Mr. Hall will handle the type of work formerly under the direction of Mr. R. H. Bacon.

Mr. Bacon has been made manager of advertising for the company, and the nature of his new position will make it necessary for him to give up the editorial contacts which he has maintained for so many years with technical publications.

C. & O. Buys Large Softening Tank

The Chesapeake & Ohio Railroad has contracted with **Graver Corporation**, East Chicago, Ind., for a settling tank for a softening plant to be built at Boston, Ind. This tank is 40 ft. in diameter by 43 ft. high and has a downtake 12 ft. in diameter.

SERVICE EXCHANGE
For
Manufacturers or Distributors

Editor's Note.—From time to time we receive letters from distributors wishing to be put in touch with manufacturers of certain lines of equipment, or from manufacturers seeking representatives for their products. Items of this kind will be published and names and addresses furnished interested persons upon request.

New Lines Wanted

Equipment distributor in Pacific Northwest desires line of road building equipment, structural building equipment, dump bodies and truck hoists.

Distributors of contractors' and builders' machinery and equipment are seeking line of road forms, road finishers, batcher plants, clamshell buckets and drag line buckets, for Northern California territory. Now stocking equipment for several well known machinery manufacturers.

Manufacturers' agents representing well-known lines of water works equipment desire to secure line of pipe pushers and other similar equipment for California and Western Nevada territory.

Road machinery distributor would like to secure exclusive sales rights for state of Mississippi for line of automatic or self-loading wheeled scraper.

A Michigan distributor, with many **years' experience, representing at this time prominent manufacturers of pumping machinery, offers the services of an established representative to manufacturers needing increased facilities in this region.**

Manufacturers' representatives located in New York would like to add line of heavy contractors' equipment of established reputation, other than the lines now handled by them. They would like exclusive sales rights for such equipment.

Canadian distributor of equipment for water softening, filtration, sewage purification and pumping is interested in securing exclusive sales rights for kindred equipment in the Dominion.

Equipment distributor located in Michigan desires to add two or three good lines to serve territory in southeastern part of state.

Distributor of building specialties covering a territory of 100 mile radius from Chicago is equipped to represent additional lines.

District respresentative for sanitary engineering specialties would be interested in any line in the water works field. Has had experience in field of filters, softeners and water meters.

Civil engineer located in Porto Rico would like to hear from manufacturers desiring sole representation for their products in Porto Rico, Santo Domingo and Venezuela. Machinery for highway construction, purification plants, steel for buildings or bridges or other building materials and contractors' equipment.

Sales representative desires business connection with manufacturer of snow plows and road machinery for Minnesota and Northwest territory.

Machinery distributor established in Porto Rico and Santo Domingo would be pleased to make arrangements to take on new lines in these territories.

A contractor's superintendent, located in Florida, would like to represent some road equipment manufacturers in his territory.

Machinery company in the east is interested in representing established lines of road machinery, with the exception of graders.

Representatives Wanted

Manufacturer of truck, adapted to many uses, has attractive territory open in Missouri, Kentucky, Kansas, Nebraska and several southern states.

Manufacturer of hoisting machinery and air compressors has open territory in New York and New England states for aggressive distributor.

Manufacturer of excavating equipment desires to build up distribution organization throughout the country.

Manufacturer of non-clogging sewage pumps, both horizontal and vertical, as well as water works pumps suitable for municipalities of 50,000 or 60,000 people, is interested in securing additional sales representation.

Manufacturer of two cycle oil and gas engines in sizes from 30 to 125 H. P. adaptable for water works and many industrial purposes, wishes to establish points of distribution throughout the country.

Manufacturer of water works brass goods, would like to make proposition to manufacturers' representatives calling on waterworks trade.

New York corporation wishes to establish agencies throughout the country, prefer men specializing in heating and ventilating equipment.

A manufacturer of paving expansion joints is looking for distributors for northern California territory.

New York corporation, producing complete line of coal-tar products, wishes to make dealer connections throughout the country.

Manufacturer has some attractive territory available for distributors for complete line of generators, and centrifugal, diaphragm and piston pumps.

Manufacturer of metal lath, corner beads, channels and reinforcing mesh desires to secure distributors for products in the Southwest and Middlewest.

Manufacturer of building specialties wishes to establish distributors throughout the country. Manufactures concrete reinforcements and metal lath; Reed clips, form spacers, continuous column tie, continuous chair stirrup, beam bar spacers, slab bar spacers, continuous Hi-chair, continuous anchor slot, sleeping spacing anchor, humpback hairpin clip, lath hanger, stone anchors, straight wire lengths and special wire lengths.

Manufacturer of threadless pipe couplings and tees, with rapidly growing business, is seeking additional representatives.

Manufacturer of metal tie and spacer wishes to establish distributing points throughout the country.

Manufacturer of mechanical spreaders for cover material desires representation by organizations covering entire states. Several desirable states are still open. Number of inquiries now on hand for spreaders require immediate follow up.

Manufacturer of automatic dipper trip, adapted to any type shovel (steam, gasoline, diesel, electric, etc.); with rapidly growing business, is seeking additional representatives.

Manufacturer of complete line of Construction Equipment, mixers, saw rigs, plaster and mortar mixers and pumps, has an open territory in the state of Maine and is looking for an aggressive distributor to represent him there.

Manufacturer of rotary pump, especially designed for road construction work, has proposition for reliable distribution houses.

European Engineers Will Witness Lincoln Automatic Welding Demonstration

Mr. J. F. Lincoln, president of The Lincoln Electric Company, recently sailed on the Leviathan for London, England, where he will take charge of a demonstration for European engineers of the Electronic Tornado process of carbon arc welding which, since its inception, has revolutionized the method of automatic welding in this country.

The demonstration will take place at The Allen Liversidge plant. It is stated the demonstration has been arranged in answer to numerous requests from enginers and manufacturers in all parts of Europe.

Diesel Engine Manufacturers Organize Association

With the rapid growth in the use of Diesel engines in all types of industrial, public utility and municipal service, as well as in the railway, automotive and marine fields, the manufacturers of Diesel engines have realized the need for a closer contact with each other and with the problems of the user. As a result, twelve of the leading builders, representing practically the entire output of Diesel engines in the United States, have organized the Diesel Engine Manufacturers' Association. The association has as its primary object, the advancement of Diesel power in America and a broad program of cooperation with the users of this type of power.

Possibly the greatest benefit to the users of Diesel power will come through the development of suitable standards of manufacturing and engineering practice. Such active problems as specifications for oil fuels, wider distribution of accepted fuels and similar subjects will have the attention of the manufacturers.

It is also the intention to promote and extend the use of Diesel power. In accomplishing this object, more information will be made available on the application of Diesel engines in all types of service. In this connection the association anticipates the helpful cooperation of the technical, trade and business press of the country in presenting the story of what Diesel power is accomplishing all through the broad range of industry.

During the past few years there has been much definite progress in Diesel engine design. The manufacturers feel that the next most important step is to take greater advantage of the economies of Diesel engines in all types of application work. In the struggle to reduce production costs in all lines of manufacturing, power cost plays such an important part that the Diesel engine is effecting marked savings. In the field of power distribution, represented by the public utility organizations, there is now a definite trend towards the use of Diesel power. In this field it is expected that the Diesel engine will play an increasingly important part as the years go by.

In marine service more than half of the tonnage now being built is equipped with Diesel engines and in the work boat field practically no other type of power is being used. The first airplanes equipped with Diesel engines have recently completed very satisfactory test flights and a number of automobile buses and trucks are being driven with this form of power.

Although Dr. Rudolph Diesel, a German engineer, is commonly given credit for the invention of the engine which bears his name, the first commercial installation was in the United States in 1893. Not much progress was made from that time until about 1912 when a number of improvements again focused attention on this type of power. The progress since that time has been rapid until today more than 4,500,000 horsepower of these engines are in marine and stationary service. Of this total, some 3,000,000 horsepower is in the United States.

In addition to its low operating cost the Diesel engine has the interesting characteristic of being just as efficient in small sizes as in large units. The largest engine to date is 15,000 hp. and is installed in a German power station. Units of 5,000 to 8,000 horsepower are becoming quite common in the marine field. It makes little difference, however, whether the engine is 50 or 10,000 horsepower, it has the same high efficiency.

Because of the simplicity of the Diesel engine with its elimination of any kind of ignition system or carburetors, it has established some remarkable reliability records. Any number of instances have been recorded where Diesel engines have operated continuously for more than a year without a single shut down. Practically all of the first Diesel engines installed in the United States, some twenty-five years ago, are still in operation.

In addition to encouraging the wider use of this efficient prime mover the manufacturers are also giving more attention to better Diesel power plant design. Although the Diesel engine is a very simple type of prime mover its satisfactory operation depends on good plant layout. Cooling water and lubrication are especially important in this field and the layout of cooling water systems has come in for considerable study. The use of lubricating oil purifiers of various types and the development of completely automatic lubrication systems have eliminated difficulties in this phase of plant operation.

With all of this increasing interest in Diesel engines, the manufacturers through their Diesel Engine Manufacturers' Association, are filling an important need in making all sorts of information available to the public with respect to Diesel engines and their operation.

The following manufacturers are members of the association:

New London Ship & Engine Works, Electric Boat Co., Worthington Pump & Machinery Corp., Fulton Iron Works Co., Ingersoll-Rand Co., Fairbanks, Morse & Co., Nordberg Manufacturing Co., I. P. Morris & DeLaVergne, Inc., Winton Engine Co., Cooper-Bessemer Corp., McIntosh & Seymour Corp., Busch-Sulzer Bros. Diesel Engine Co., Hooven, Owens, Rentschler Co.

The president of the association is Henry R. Sutphen, president, Electric Boat Co.; E. T. Fishwick, vice-president of the Worthington Pump & Machinery Corp., is vice-president of the association; and Harlan A. Pratt, manager oil and gas engine department of Ingersoll-Rand Co., is secretary and treasurer. The association also employes M. J. Reed as research engineer, with headquarters at the association office, 30 Church St., New York City.

Bay City Shovels Expects New Offices to Be Ready for Occupancy in October

Bay City Shovels, Inc., of Bay City, Michigan, is looking forward to occupying early in October the new office building which is now in the course of construction under the direction of the Henry C. Weber Construction Company. The new building is being located on the Shovel Company property adjoining the factory and is of modern fireproof construction, reinforced concrete foundations and floors with hollow clay tile and face brick walls. The top floor will be occupied by the drafting room and engineering department, as well as an auditorium, and each floor will be provided with a fireproof storage vault.

The construction of the new office building is following out a previously announced expansion program, the first step of which is now completed in the new fireproof factory building equipped with an electric overhead traveling crane and containing 18,000 sq. ft. of floor space available for the assembly department. Mr. Morgan Ramsay, one of the officials of the company, states that the increased facilities were made necessary to meet the demand for the Bay City power shovels, and the machine shop division is now operating in day and night shifts.

Chicago Pump Company announces that Sprekelmeyer-McDonald Company, 709 Pennsylvania Avenue, Ft. Worth, Tex., has been placed in charge of that territory.

I. F. Baker to Direct Foreign Sales for Westinghouse

Mr. I. F. Baker, who has served the interests of the Westinghouse Electric and Manufacturing Company in many capacities since his apprentice days in 1909, has recently been appointed European sales manager of the Westinghouse Electric International Company and will be located at No. 2 Norfolk Street, Strand, London.

In 1913 Mr. Baker was transferred from the industrial sales department to the Westinghouse Export Company at East Pittsburgh, and in 1918 was transferred to the New York office of Westinghouse International, only to be sent the following year to Japan. While in Japan he became prominent in commercial and engineering affairs, serving as president of the American Merchants' Association of Tokyo and acting president of the American Association of Tokyo.

Just previous to Mr. Baker's appointment to the post in England, he had been power division sales manager of the Westinghouse Electric International Company, with offices in New York. It is said that Mr. Baker's efforts while in Japan contributed largely to the installation of one and a quarter million kv-a. of rotating apparatus, and two and a quarter million kv-a. of transformer equipment.

Universal Power Shovel Factory Moved to Milwaukee

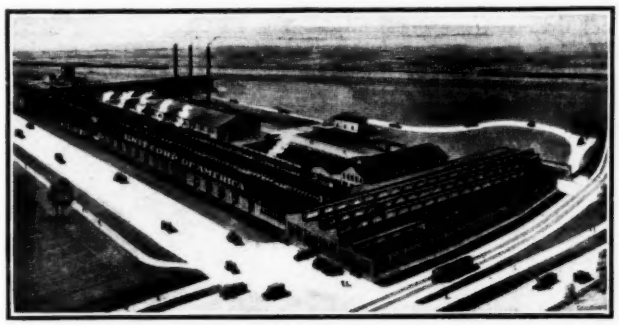
Announcement has recently been made of the removal of the factory and personnel of the Universal Power Shovel Company from Detroit to Milwaukee.

This company, which has been manufacturing excavating and material handling equipment for several years, was acquired a few months ago by the Unit Corporation of America, and since that time increased sales have made necessary better production facilities.

The new factory, located at Milwaukee, Wis., has just been completed. It is expected that the ample floor space and new, modern machinery will adequately meet the requirements of the company. Straight line assembly operations have been installed, and scientific production methods have been applied to the manufacture of the new line of gasoline power shovels, cranes, clamshells, draglines and backfillers.

Orders for machines and service parts are assured prompt handling because of the convenience of the plant's location for incoming and outgoing freight.

Headquarters in the new Bankers' Building, Milwaukee, have been established for the executive offices. The Universal Power Shovel Co. will continue to be represented in Detroit, Mich., with a branch office located at 462 Book Building.



Universal Power Shovel Co.'s New Factory at Milwaukee, Wis.

General Electric Pays Supplementary Bonus

The General Electric Company on Aug. 6 paid $1,825,832 in supplementary compensation to its factory and office employees who have been in the service of the company for five years or longer. This is the largest bonus ever paid by the company and represents five per cent of the earnings of employes for the six months ending June 30. Approximately one third of the total, or $584,342, was paid to employees at the Schenectady works.

During the past five and one-half years the company has paid a total of $15,757,722 in supplementary compensation to its employees under this bonus plan.

Announcement

The board of directors of International Combustion Tar & Chemical Corporation announces the election of George E. Learned as chairman of the board, succeeding F. J. Lewis; Dr. Walter Runge as president, succeeding W. H. Lewis; and Grant Thorn as vice-president in charge of sales.

It is stated that the resignations of Messrs. F. J. and W. H. Lewis were due to pressure of other business activities. Mr. J. F. Lewis will continue to serve as director of the International Combustion Engineering Corporation, of which the Tar and Chemical company is a subsidiary, and Mr. W. H. Lewis will be associated with it in an advisory capacity.

H. C. Collins to Represent Link-Belt in West

The crane and shovel division of Link-Belt Company, Chicago, announces the appointment of Mr. Harry C. Collins as its official representative in southern California, with offices in Los Angeles.

He will handle the Link-Belt line of shovels, cranes and draglines, devoting his entire time to but two lines—the other one being Plymouth locomotives, made by the Fate-Root-Heath Co., Plymouth, O.

H. C. Collins

For the past several years Mr. Collins has been president of the Collins-Kay Machinery Company, a position that he resigned from July 1 so that he might serve Link-Belt and Plymouth exclusively.

Mr. Collins is reported to be well and favorably known throughout southern California, this being the district he has served for the past 25 years, for seven years of which he was connected with Allis-Chalmers in the capacity of sales engineer.

During the remaining 18 years he has been in business in Los Angeles as a manufacturers' agent, handling general engineering work and heavy construction equipment for dams; municipalities; counties; sand, gravel and rock plants, and for contractors.

The Galion Iron Works & Manufacturing Company, Galion, O., announces the election of Mr. John L. Connors to the board of directors. Mr. Connors has also been made assistant general manager of this company.

R. W. Proctor Joins Cleveland Office of Van Dorn Co.

An announcement of interest to jobbers in the shop equipment field is to the effect that Mr. R. W. Procter, known to his friends as "Doc," has left the Black and Decker organization to become general sales manager of the Van Dorn Electric Tool Company. Mr. Procter has moved to Cleveland, where he will devote all his time and energy to promoting sales of the Van Dorn products.

The joy with which Mr. Procter is being greeted in his new undertaking is expressed by Mr. F. H. Zulauf, vice-president of the Van Dorn Electric Tool Company, in the following words:

"I believe that practically all of our jobbers who know him will agree that no man in our industry ever lost more hair in his sincere desire to help jobber distribution than R. W. 'Doc' Procter of the Black & Decker Manufacturing Company. If there is a manufacturer's man more loyal to the jobbers' cause, or one who has done more to help promote jobber distribution in the shop equipment field, I don't happen to know him. It is unnecessary for me to dwell on the qualifications of Mr. Procter as a merchandiser and sales executive, as his ability in this direction is well known and respected throughout the jobbing fraternity."

Westinghouse Acquires Newark Site for Service Shop

The Westinghouse Electric and Manufacturing Company recently purchased in Newark, N. J., a 22-acre site for a new warehouse and service station. It is planned that this new shop will serve the entire northern New Jersey industrial area.

Located at Haynes Ave. and State Highway, in the Port Newark Development, the site is conveniently located. The city of Newark contemplates building a belt line, connecting all of the railroad trunk lines, and is engaged in an elaborate program of highway improvements and grade crossing removal for this district.

General Electric Announces Change in Employees Insurance Plan

The General Electric Company has announced a revision in their group insurance plan so that premiums paid by new employees will be in accordance with their age, rather than an average rate common to all. President Gerard Swope also announced a modification of the plans for free insurance and additional pensions, also equalizing benefits according to age.

Heretofore, under the free insurance plan, the company furnished the same benefits to all employees, regardless of age. Under the revision the amount of free insurance given the company to new employees will vary according to the age of the person at the time he enters the service.

It is stated that the General Electric Company has more than 80,000 employees at the present time, and has in force a group life insurance policy amounting to more than $160,000,000. There are now approximately 1,000 former employees receiving pensions of disability relief and the pension trust has been built up to almost $9,000,000.

R. B. Marshall Joins Chain Belt Co.

Robert B. Marshall, well known conveyor sales engineer, has joined the Chain Belt Company's Conveyor Division with headquarters at the company's New York City office at 50 Church St. Mr. Marshall has spent the past 21 years in the conveyor business. In addition to the complete line of Rex Conveyors, he will handle the belt conveyors, glass batch handling equipment and silo storage system manufactured by the Stearns Conveyor Company of Cleveland a division of the Chain Belt Co. W. H. Quinn is the New York district manager for the company.

General Electric Exhibit at Aeronautical Exposition

The General Electric Company, according to announcement, a varied and interesting exhibit at the National Air Races and Aeronautical Exposition held in Cleveland Aug. 24 to Sept. 2.

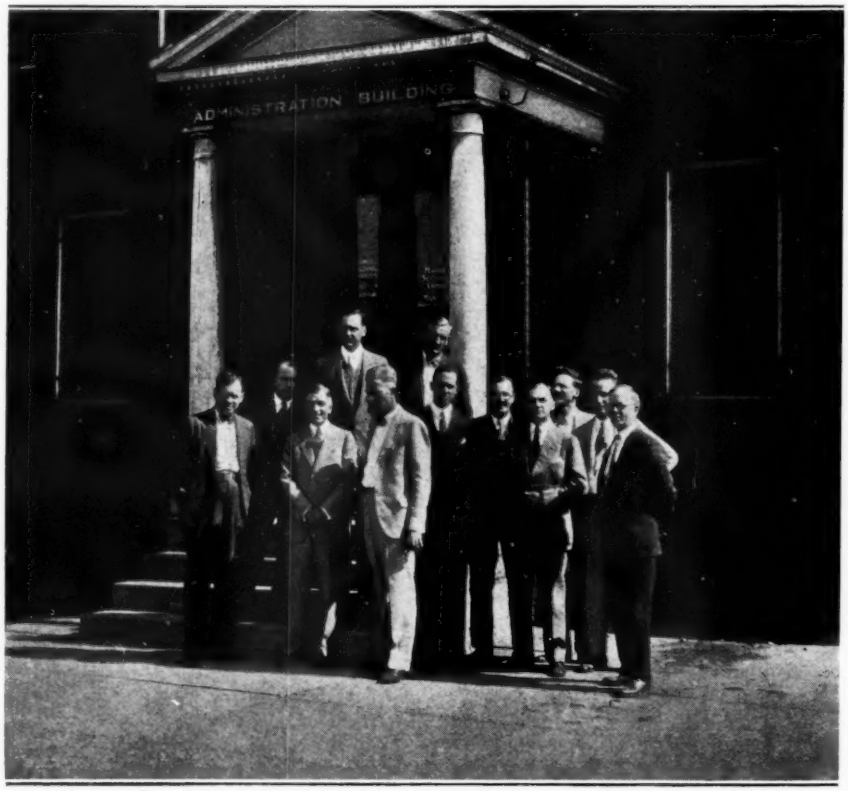
Included in the exhibit were airport beacon lights, floodlights, magneto compass, magnetic compass and airplane engine supercharger.

Representatives of the G. E. Company include H. C. Ritchie, A. H. French and R. Stearns.

Wagner Electric Corporation of St. Louis announces that their Mr. Ralph R. Rugheimer is now a member of the Atlanta branch sales office. Mr. Rugheimer has spent quite a few years in the early days of his training on construction and central station work, and was five and one-half years with the Westinghouse company. He is a native of South Carolina, and a graduate of Newberry College in Electrical Engineering of that state.

Wagner Electric Corporation of St. Louis announces the transfer of F. C. Hosimer from the home office to the Chicago branch. Mr. Hosimer entered the employ of the Wagner Company while a student engineer at Purdue University and has been employed as sales correspondent.

Graver Corporation has appointed Mr. William E. Dunbar as Southeastern sales engineer. Mr. Dunbar will be located at Florida Theatre Building, Jacksonville, Fla. His territory will include the states of Florida, Georgia and Alabama. Mr. Dunbar is no stranger to his territory nor the equipment he is selling, as he has been engaged in the water softening and filtering business in this territory for many years.



Sales Force Representatives, Manitowoc Engineering Works. Upper Row—J. A. Forsythe and J. A. Egan. Middle Row—C. H. Moore, C. C. Miller, R. A. Chadwick, E. B. Nickles and M. G. Hennessey. Lower Row—T. O. Putt, J. E. Thiell, J. W. Frain, F. C. King and J. J. Reilly